1958

Variability in reed canarygrass, Phalaris Arundinacea L.

Arden Albert Baltensperger

Iowa State College

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VARIABILITY IN REED CANARYGRASS,

*Phalaris arundinacea* L.

by

Arden Albert Baltensperger

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Crop Breeding

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Professor in Charge of Farm Crops

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

1958
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INTRODUCTION

The amount of genetic variability existing in a species is of utmost importance in efforts to breed better varieties. In initiating a breeding program with any crop, a survey of the nature and amount of variation within the species for traits of agronomic importance is desirable, since such information may guide the investigator in determining the most effective breeding procedures. In the present study, the variability existing in reed canarygrass, Phalaris arundinacea L., was the primary concern, and a large collection of seed lots diversified in origin constituted the basic materials evaluated.

Reed canarygrass is known to be a perennial grass of wide adaptation, characterized by high forage yields and satisfactory aftermath following grazing or cutting. This grass is used primarily in low wet areas and for controlling gullies even though it produces good forage yields on upland soils and has been found drought tolerant. On the other hand, several undesirable features decidedly limit increased utilization of this species for forage purposes. Foremost among these are the difficulty of obtaining sufficient quantities of high quality seed at a reasonable price and questionable quality of forage from a feed standpoint. The former limitation is due primarily to the extreme seed shattering suscep-
tibility exhibited by the species in general. Reasons for the latter are unknown, since compositional studies generally show no serious deficiencies. From a breeding standpoint, therefore, development of strains with good shattering resistance, seed quality, seedling vigor, and leafiness should help in extending the range of usefulness of this species in grassland farming programs.

Up to the present time little information has been obtained concerning possible genetic variability for these or any other traits of importance in reed canarygrass. Also, knowledge of interrelationships among agronomic characteristics in this species is lacking. To obtain information on these points, a number of open-pollinated seed lots from bulk head collections and commercial seed companies in addition to three clones were used to establish forage and seed yield tests, a replicated space-planted nursery and a shattering experiment for intensive study. The main objectives of the investigation were as follows: to measure differences among plantings of seed lots obtained from divergent sources as to forage and seed productivity, to measure plant-to-plant variability in various accessions and estimate the extent to which this variability is genotypic, to study interrelationships among certain characters, to compare performance of accessions in spaced and broadcast plantings and to study seed shattering. It was hoped that results obtained in these
studies would provide the nucleus for the organization of a program designed to breed an improved reed canarygrass.
LITERATURE REVIEW

Although reed canarygrass, *Phalaris arundinacea*, has a broad area of adaptation and possible utilization, there has been little breeding work reported concerning this species. Literature pertaining to breeding, genetics and cytology of a number of other grasses has been reviewed extensively by Atwood (7), Hanson and Carnahan (28), Hayes, Immer and Smith (32), Myers (56) and Smith (66) and will not be included. This review includes information concerning agronomic and botanical aspects, composition of the forage, and genetics and cytology of reed canarygrass together with breeding literature on other grasses pertinent to this study.

Agronomic and Botanical Aspects

Reed canarygrass is a perennial forage grass with a spreading growth habit. It is indigenous to several continents (33). General discussions of the distribution adaptation, culture and utilization are given by Heath and Hughes (33), Hoover et. al. (36) and Wheeler (76). Its early history was discussed by Alway (2).

A description of the general morphology and especially the time of initiation of inflorescence is of interest in connection with experimental treatment of breeding material
in any species. Evans and Ely (18) noted that in reed canarygrass the upper branches of the inflorescences spread before and during flowering. In their study flowering occurred from June 1 to June 18 and panicked culms had from seven to nine leaves. The authors also discuss the time and place of origin of above ground shoots. Holt (35) studied the time of inflorescence initiation and the sequence of organ initiation in this species.

Reed canarygrass is adapted and found growing throughout much of the northern half of the United States and has been found to be especially adapted to low, wet areas. Several authors (10, 54 and 77) have attested to its retention of seed viability through long periods of flooding and to its capacity as an established plant to thrive in water for periods as long as seven weeks. Reed canarygrass has also been shown to produce high yields of forage on upland soils and even under drought conditions. Wilkins and Hughes (78) reported reed canarygrass was more productive and drought tolerant than several other grasses including smooth bromegrass, timothy and orchardgrass. Similar results have been found in England (59).

Reed canarygrass was the most productive perennial forage grass tested in Illinois (37) and Iowa (33). Over a four year period, Wilkins and Hughes (78) found yields in tons of dry matter per acre of 2.06, 1.45, 1.44 and 0.83 for reed
canarygrass, brome grass, timothy and orchardgrass, respectively. Washko and Pennington (74) also found that this species produced high annual forage yields and high yields of aftermath when tested under conditions of satisfactory rainfall in Pennsylvania. These authors also reported forage yields, averaged over three years and four locations, of 3.24 tons of dry matter per acre compared with 3.45 and 2.75 for orchardgrass and brome grass, respectively. Aftermath production, as measured by second cutting yields, was 1.06, 1.17 and 0.67 tons of dry matter per acre for reed canarygrass, orchardgrass and smooth brome grass, respectively. In Denmark, Foss (22) found that reed canarygrass yielded somewhat less forage than timothy.

One of the serious objections to reed canarygrass as a cultivated forage plant is its seed shattering characteristic. Seed often shatters from upper branches of the inflorescence while seeds at the base are still immature. Numerous reports of this problem and the need for improvement have been made in this and other countries (6, 12, 19, 26, 59, 63 and 67). The difficulty of harvesting satisfactory quantities of seed is emphasized by numerous reports on the optimum time and method of harvest (52, 78, 80 and 81). Griffeth (24) found that seed could be harvested most satisfactorily when about 50 percent of the seeds were brown. Wilkins and Hughes (78) reported largest yields of quality seed when five percent of
the seeds had shattered, while MacVicar and Childers (52) stated that the optimum time of harvest was 22 to 29 days after blooming. Even if optimum harvest periods are observed, seed yields are low. In Canada, White, et al. (77) reported seed yields ranging from 35 to 390 pounds per acre. In Minnesota, Arny (4) found seed yields of 40 to 100 pounds per acre most frequently; however, on a few fields where stands of panicles were thick, yields of 250 to 390 pounds of seed per acre were obtained.

Quite often germination of reed canarygrass seed is low. Griffeth (24) measured percent germination and seed yield using three methods of harvest. The results for a beater, a binder and a combine-type harvester were 15, 79 and 414 pounds of seed per acre of 99, 74 and 44 percent germination, respectively. Seed viability in reed canarygrass varied with stage of maturity, according to reports by Arny (4) and Arny, et al. (5). They found that mature seeds, as judged by darkness of color, gave highest germination. Griffeth and Harrison (25) showed that seed maturing on the plant usually had the highest germination and that high moisture in the seed and high temperatures during curing often reduced germination.

The low yield and poor viability of reed canarygrass seed would be improved if seed shattering could be reduced by plant breeding. However, Hanson and Carnahan (28) have observed that much of the variation in seed shattering can be attrib-
uted to differences in maturity rather than inherent differences in ability to hold seed after maturity. Hertzsch (34), in Germany, recently irradiated reed canarygrass seeds and found a number of plants in the $X_2$ generation that he classed as mutants. Among these were plants showing non-shedding grains. The Superior strain developed in Oregon is reported to show somewhat less tendency to shatter seed (33); however, it is not sufficiently winter hardy for use in much of the north central part of the United States. Ioreed, a strain developed in Iowa by combining several clones that appeared high in seed production, also presents a problem in seed shattering. Thus, any information concerning variability within reed canarygrass for seed shattering that is independent of maturity would be of use in connection with a breeding program designed to improve this characteristic of the species.

Another factor related to seed production is the amount of self- and cross-fertility in a species. Information pertaining to this point also is important when initiating a breeding program. Smith (65), in a study of 20 reed canarygrass plants, found that selfed plants averaged 0.018 seeds per floret, while cross pollinated plants averaged 0.429 seeds per floret. Keller (41) noted 106 bagged plants set an average of 1.8 selfed seeds per inflorescence. In general agreement with the previous information on self-fertility,
Ficke (21) found that 300 selfed panicles produced an average of 11.86 seeds per panicle or a seed set of about three percent. Of the seeds produced, only 33 percent germinated. Thus, only about one percent of the florets set germinable seed when self-pollinated. Beddows (9) also noted a high degree of self-sterility in reed canarygrass.

Composition of Forage

Chemical composition of plants has often been used as an indication of nutritive value and in some cases it is considered as a guide to palatability. Archibald, et al. (3) summarized seven years of investigational work on chemical composition and palatability to cattle of certain grasses and legumes. On a preference basis, rating of the grasses was in order of vitamin A content and generally in the order of succulence. Crude protein content apparently had little relation to palatability. Reed canarygrass, however, was not included in this study. Studies pertaining to chemical composition by Plummer (58), Phillips, et al. (57) and Washko and Pennington (74) showed reed canarygrass to be high in carotene, protein and minerals but low in lignin and crude fiber. This species compared favorably with other grasses including smooth bromegrass, orchardgrass and timothy. Feldt and Hertzsch (20), in Germany, reported that mixed forage stands containing reed
canarygrass were higher in protein than stands without it. Amy et al. (6) and Weber (75) found the highest crude protein percentage in reed canarygrass hay if cut when inflorescences were beginning to shoot rather than later, and Schwarz (64) found the highest yield of protein at commencement of flowering.

Some later maturing species of grasses have been found by Phillips, et al. (57) to be lower in protein content than earlier ones. Sullivan and Routley (68) noted that high protein percentage was associated with earliness in orchardgrass. However, this was not true of reed canarygrass where the correlation between protein percentage and date of heading was not significant, r = 0.05. This would indicate that selection for desired later maturity may not necessarily effect a change in the protein content of reed canarygrass.

Reports concerning the palatability of reed canarygrass vary considerably. Van Arsdell, et al. (72) found generally poor results from reed canarygrass in a pasture study with steers. Animals were unthrifty in appearance and made poor gains. Seldom did any of the steers, except on one pasture, appear as if they were eating more than enough to satisfy hunger only partially. Other workers (8, 17, 40, 61, 69 and 73) have reported similar questionable or poor palatability for either hay or pasture when trials were conducted using different kinds of livestock. Rogler (62) measured the amount
of foliage removed from ten cool-season grasses by cattle and reed canarygrass was the least eaten. Beaumont, et al. (8) determined that toughness or breaking strength did not seem to be the cause of unpalatability since reed canarygrass was less tough than other species tested. It is not surprising that this grass has been found more palatable when pastured close (5, 8, 12 and 73) or when hay is harvested at an early stage (33, 79).

In contrast to these reports of poor palatability, cases of satisfactory palatability have been observed. Alway (2) states that Hesselgren of Sweden found this species to be one of the most palatable grasses when fed as hay to several kinds of livestock. Wilkins and Hughes (78) observed that horses preferred reed canarygrass to timothy as hay.

An insight into the possible lack of palatability or nutritional value of reed canarygrass may be found by more detailed chemical analyses. Kik and Staten (43) determined the amino acid content of a number of grasses including reed canarygrass and their report shows this species to be lower in glutamic acid and threonine than orchardgrass or tall fescue. The nutritive value of immature reed canarygrass was found by Crampton and Finlayson (16) to be less than that of immature timothy, although there was no qualitative difference between these two grasses in crude protein, calcium, phosphorus or total nutrients. Kirsch (45), in a six year test
in Germany using dairy cows, found that the nutritive value of reed canarygrass hay was lower than for orchardgrass and timothy cut at the same stage of growth; however, because of the greater yields, the amount of milk obtained per unit of land area was greatest for reed canarygrass.

Genetics and Cytology

Literature pertaining to the cytology and genetics of a number of forage grasses was reviewed by Atwood (7), Myers (56) and Smith (66). Several investigators cited by Myers reported the somatic chromosome number of *Phalaris arundinacea* as 28. More recently, Hanson and Hill (29) reported a range of 27 to 35 in the somatic chromosome number of this species and of the 186 plants of diverse origin studied, 9 percent were aneuploids. On the basis of regular observation of 14 bivalents at diakinesis, they concluded that *P. arundinacea* probably is an allopolyploid. Though *P. arundinacea* is generally considered to be a tetraploid, Carnahan and Hill (13) found hexaploids and octoploids in progenies from three natural pentaploid plants. Correlations of some morphological characters with chromosome numbers also were computed.

There are several reports of interspecific hybrids of *P. arundinacea* x *P. tuberosa* (14, 38, 60 and 70). Covas and Cialzeta (15), in Argentina, treated roots of male sterile F₁
hybrids from this cross and obtained fertile polyploids with roughly 56 chromosomes. They noted these plants had longer panicles and seeds and considered this a promising source of selection material. Jenkin and Sethi (38) also obtained F₁ plants of this interspecific cross that were male sterile. However, these plants were female fertile and seed set was thought to be due to *P. tuberosa* pollen.

Phenotypic and Genotypic Variation

Most grass breeding programs are initiated by evaluating individual spaced plants in source nurseries. Selection on this basis may be of most value in effecting genetic advance for characters which are highly heritable. Measurements of plant-to-plant variability in space-planted nurseries have been useful for studies of the nature and extent of variation which exists in plant populations (11 and 49). Trumble (70), in a study of *P. tuberosa*, found that lines from different sources generally showed greater variation within the lines than among lines, although some lines contained a greater proportion of desirable types than others.

The proportion of the total (phenotypic) variation for any trait within a species that is genotypic is of importance in a breeding program. Heritability estimates may be made by calculating this genotypic variation. Burton (11) estimated
heritability in pearl millet by partitioning total variance of the $F_2$ generation into environmental ($F_1$) and genotypic ($F_2$ minus $F_1$) variance components. He found yield differences due almost entirely to environmental effects, while plant height and leaf width were due largely to genotypic effects. Lebsock and Kalton (49) found that variation within spaced-planted seed populations of smooth bromegrass was two to three times greater than variation within clones planted in the same manner. From these variance values they obtained estimates of genotypic variation of 46, 60, 67 and 86 percent for fall vigor, hay vigor, leaf width and plant height, respectively.

Heritability estimates for yield and spread in $S_1$ progenies of bromegrass clones were found to be negative or approximately zero by McDonald, et al. (53). It was concluded that selection for such characters as yield and spread in spaced plantings would be of doubtful value. Variability in plant height was about half genotypic in this study. Kalton, et al. (39) obtained genotypic variances for yield and panicle number that were negative or low among $S_1$ orchardgrass plants. For spring vigor score, leafiness score and plant height, on the other hand, heritability estimates of 51, 39 and 42 percent, respectively, were obtained. No information relating to such variability in $P. arundinacea$ for important plant characters, other than for fertility, was found in the litera-
Possible progress from phenotypic selection in isolated space-planted nurseries was indicated by Harlan (30) in a study with side-oats grama. He was successful in fixing narrow- and wide-leaf width types, though abundance of leaves was less amenable to change by phenotypic selection.

Intercharacter Relationships

Intercharacter associations, especially the genotypic portion, also are of interest since they give some indication of the possibility of obtaining desirable combinations of characters in breeding material. Studies with bromegrass (23, 27, 31, 44, 49, 51 and 71) and orchardgrass (39 and 50), although not entirely consistent, generally indicate the following:

(1) positive and strong relationships among spring vigor, yield and leafiness.

(2) positive and high correlations between hay vigor and fall vigor, spread, height and aftermath growth.

(3) leaf width independent of vigor traits and leafiness.

(4) spring vigor and forage yield strongly related to panicle production.
(5) positive and high correlations between fertility and seed yield.

Correlations among agronomic characters of pearl millet were partitioned into genotypic and environmental components by Burton (11). Genetic correlation coefficients were calculated by application of the formula,

\[
\frac{\text{Cov}_{XY}^{F_2} - \text{Cov}_{XY}^{F_1}}{(V_{X}^{F_2} - V_{X}^{F_1})(V_{Y}^{F_2} - V_{Y}^{F_1})},
\]

where Cov and V represent covariances and variances in the F₁ and F₂ populations. In a study of bromegrass, Lebsock and Kalton (49) reported high phenotypic correlations between hay vigor and fall vigor, spread, height and recovery, while leaf width proved essentially independent of vigor attributes. Genetic and environmental correlations provided little additional information. Grennell (23) reported genetic correlations tended to parallel phenotypic correlations closely in bromegrass and only the association of seed yield per panicle with fertility was significantly effected by environment.

**Planting Method Comparisons**

Another factor that must be considered by plant breeders is that of planting methods for evaluation purposes. In this regard, it is important to know to what extent characteristic differences observed in space-planted nurseries are similarly
measured in solid stands of the same or related progenies. In a study of Kentucky bluegrass, Algren, et al. (1), concluded that growth and appearance of spaced plants cannot be used to predict closely the performance of the same progenies in mass seedings. Kramer (48) observed a lack of association between characteristics of bluegrass plants in spaced and solid plantings. McDonald, et al. (53) found a low association between yields of drilled rows and space-planted open-pollination progenies of bromegrass. Guenther (27) concluded from a study of bromegrass that selection of clones on the basis of yield as spaced plants would result in no improvement in yielding ability in solid seedings. In studies of crested wheatgrass, Knowles (46) found little relationship between yield of parent clones and their progeny classes. Also, Kramer (47) has stated that, in general, space-planted plots were of value only for evaluating a few highly heritable characters.

Hawk (31) found significant positive correlations between clonal yields in replicated rows and spaced plantings. Also, yields of both clonal rows and spaced plantings were positive and significantly correlated with yields of their open-pollination progenies planted in drilled rows. Relationships of different planting methods were investigated for bromegrass, orchardgrass and red rescue by Murphy (55). He concluded that spaced-planted rows, drilled rows, or broadcast
plots could be used for isolating plants possessing a high yield potential. The performance of bromegrass in a space-planted nursery was indicative of forage productivity in solid stands the first year after seeding, according to Lebsock and Kalton (49).
MATERIALS AND METHODS

The basic plant materials studied in this investigation were mostly from seed collections. Forty-three seed lots were collected in the United States and one each came from Turkey and Canada. In addition, three vegetatively-propagated clonal selections, from Ioreed, Superior and a plant found growing in a fence row, respectively, were used. A list of breeding materials included in this study and their sources is presented in Table 1. Accession numbers Ph-2 to Ph-33 in the table came from bulked individual head collections selected for apparent resistance to seed shattering at maturity. The source materials mentioned were used in one or more phases of the investigation which consisted of four parts, namely, forage yield tests, seed yield tests, replicated space-planted nursery and a seed shattering experiment.

Forage yield tests were established with oats as a companion crop at Ames and Cresco, Iowa, in the spring of 1955. Included as entries were 18 accessions of reed canarygrass, two strains of orchardgrass and one strain of smooth bromegrass. Seed was drilled in rows 8 inches apart, in five-by nine-foot plots at recommended seeding rates. Each plot was delimited on all sides by a single drilled row of alfalfa. A split-plot design with planting methods, alone and with Ladino clover, as whole plots and entries replicated five times as
Table 1. Sources of reed canarygrass breeding material

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<th>Iowa accession number</th>
<th>Location or source</th>
<th>Source remarks</th>
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<td>Ph-2</td>
<td>5 mi. N.W. St. Michael, Minn.</td>
<td>Hayfield</td>
</tr>
<tr>
<td>Ph-3</td>
<td>10 mi. N.W. Monticello, Minn.</td>
<td>Hayfield</td>
</tr>
<tr>
<td>Ph-4</td>
<td>West edge of St. Cloud, Minn.</td>
<td>Peat bog</td>
</tr>
<tr>
<td>Ph-5</td>
<td>20 mi. S. of Minneapolis, Minn.</td>
<td>Peat bog</td>
</tr>
<tr>
<td>Ph-6</td>
<td>Fairchild, Cresco, Ia.</td>
<td>Waterway</td>
</tr>
<tr>
<td>Ph-7</td>
<td>Howard Co. Exp. Farm, Ia.</td>
<td>Pasture</td>
</tr>
<tr>
<td>Ph-8</td>
<td>2 mi. E. Amboy, Minn.</td>
<td>Pasture</td>
</tr>
<tr>
<td>Ph-9</td>
<td>5 mi. N.W. Minn. Lake, Minn.</td>
<td>Pasture</td>
</tr>
<tr>
<td>Ph-10</td>
<td>3 mi. W. Waseca, Minn.</td>
<td>Pasture</td>
</tr>
<tr>
<td>Ph-11</td>
<td>5 mi. N.W. Minn. Lake, Minn.</td>
<td>Pasture</td>
</tr>
<tr>
<td>Ph-12</td>
<td>West edge of Easton, Minn.</td>
<td>Ditch bank</td>
</tr>
<tr>
<td>Ph-13</td>
<td>4 mi. E. &amp; 2 mi. S. Mapleton, Minn.</td>
<td>Pasture-Some shattering resistance</td>
</tr>
<tr>
<td>Ph-14</td>
<td>1 mi. E. Forest City, Ia.</td>
<td>Pasture</td>
</tr>
<tr>
<td>Ph-16</td>
<td>Howard Co. Exp. Farm, Ia.</td>
<td>Hayfield</td>
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<tr>
<td>Ph-18</td>
<td>4 mi. W. Goodell, Ia.</td>
<td>Ditch bank</td>
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<td>Ph-20</td>
<td>W. edge Wells, Minn.</td>
<td>Slough</td>
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<td>Ph-21</td>
<td>5 mi. S. Waseca, Minn.</td>
<td>Seed field</td>
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<td>10 mi. N. Wells, Minn.</td>
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<td>Ph-28</td>
<td>3 mi. W. Garnanillo, Ia.</td>
<td>By I. L. Christensen</td>
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<td>Ph-29</td>
<td>Rule, Warren Co.</td>
<td>By V. B. Hawk</td>
</tr>
<tr>
<td>Ph-30</td>
<td>Kinsey, Marengo, Ia.</td>
<td>Hayfield (by R. H. Bush)</td>
</tr>
<tr>
<td>Ph-33</td>
<td>Bulked seed; 5 farms near Primghar, Ia.</td>
<td>By R. P. Lathrope</td>
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*Names in this column refer to seed growers.*
Table 1. (Continued)

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<td>Ph-36</td>
<td>Kinsey, Marengo, Ia.</td>
<td>By R. H. Bush</td>
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<td>Ph-38</td>
<td>Kellen, Donnelly, Minn.</td>
<td>Newday Seedsmen, Fargo, N. Dak.</td>
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<tr>
<td>Ph-40</td>
<td>Drewes, Morris, Minn.</td>
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<tr>
<td>Ph-44</td>
<td>Lacombe, Alberta (P.I. 220,359)</td>
<td>Dr. A. A. Hanson, Beltsville, Md.</td>
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<td>Ph-47</td>
<td>Koehler, Charles City, Ia.</td>
<td>By G. Summers</td>
</tr>
<tr>
<td>Ph-49</td>
<td>Miller, Waseca, Minn.</td>
<td>Minn. Seed Co., Faribault, Minn.</td>
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<td>Ph-50</td>
<td>Evans, West Concord, Minn.</td>
<td>Minn. Seed Co., Faribault, Minn.</td>
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<td>Ph-51</td>
<td>Youngberg, Otisco, Minn.</td>
<td>Minn. Seed Co., Faribault, Minn.</td>
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<td>Ph-56</td>
<td>Vaughn, Waseca, Minn.</td>
<td>Frmrs Sd &amp; NrsyCo., Faribault, Minn.</td>
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<td>Ph-57</td>
<td>Clarkin, Montgomery, Minn.</td>
<td>Frmrs Sd &amp; NrsyCo., Faribault, Minn.</td>
</tr>
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<td>Ph-58</td>
<td>Taylor, Elysian, Minn.</td>
<td>Frmrs Sd &amp; NrsyCo., Faribault, Minn.</td>
</tr>
<tr>
<td>Ph-60</td>
<td>Turkey Introduction (P.I. 172,443)</td>
<td>P.I. Station, Ames, Ia.</td>
</tr>
<tr>
<td>Ph-61</td>
<td>Ioreed - Syn. 4</td>
<td>S.C.S., Elsberry, Mo.</td>
</tr>
<tr>
<td>Clones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-1</td>
<td>Superior strain, developed in Oregon</td>
<td>S.C.S., Ankeny, Ia.</td>
</tr>
<tr>
<td>I-1</td>
<td>Ioreed strain, developed in Iowa</td>
<td>S.C.S., Ankeny, Ia.</td>
</tr>
<tr>
<td>R-5</td>
<td>Plant from fence row, Ames, Ia.</td>
<td></td>
</tr>
</tbody>
</table>
subplots was used at Ames, Iowa. All plots were grown in association with Ladino clover in a randomized complete block design with five replications in the experiment at Cresco. Plots of grass alone were uniformly top-dressed with approximately 200 pounds of 33-0-0 fertilizer per acre in the spring of 1956 and 1957.

The tests were clipped for removal of the companion crop and to reduce weed growth during the year of establishment. Stand was estimated in percent and spring vigor was scored from 1 (most) to 9 (least) in May of 1956. Stands of both reed canarygrass and Ladino clover were generally fair at Ames and good at Cresco. Forage was harvested whenever the reed canarygrass was about 12 to 14 inches tall, as pictured in Figure 1, in an effort to simulate grazing. In 1956, two harvests were made at Ames and three at Cresco. Three harvests were taken at both locations in 1957. Yields were obtained by mowing a strip three by six feet through the center of each plot and were recorded to the nearest one-hundredth of a pound of oven-dry weight. Data from only the 1957 Ames test were analyzed using analyses of variance for each cutting and total annual yield. Data from Cresco were analyzed for each cutting, total annual yields and years combined.

The seed yield tests were established at Ames and Cresco in the spring of 1955 using randomized complete block designs with five replications. Each plot consisted of a single,
Figure 1. Forage yield test showing plots of reed canarygrass and Ladino clover

Figure 2. A portion of the space-planted nursery over-seeded with alfalfa (note differential winter survival)
drilled row 19 feet long. Row widths were 3 1/3 and 3 1/2 feet at Ames and Cresco, respectively. Included as entries were 28 of the reed canarygrass accessions listed in Table 1. Fertilizer was applied at the rate of 250 pounds of 33-0-0 per acre on the test at Ames in the spring of 1956, while no fertilizer was applied at Cresco. In the spring of 1957 the tests at both locations were fertilized with 200 pounds 33-0-0 and 300 pounds of 4-16-8 per acre.

Data taken on the seed yield tests included: percent stand, spring vigor, date of bloom, panicle production, seed yield and percentage germination of seed. Stand and spring vigor notes were taken as described for the forage tests. Plots were considered in bloom when approximately one-half of the panicles were in anthesis. Panicle production was scored from 1 (least) to 5 (most) at both locations in 1956. In 1957, panicles were counted in a linear three-foot sample of each row plot at both locations. Seed was harvested at both locations for two years when approximately 50 percent of the seeds were brown. A composite of harvested seed from the five replications of each entry at Cresco was used to determine percent germination in 1956. Yield data were analyzed statistically and correlation coefficients of panicle production with seed yield were computed using standard procedures.

The third part of the study consisted of a space-planted
nursery established in 1955 at the Agronomy Farm, Ames, Iowa. Included in this nursery were 39 seed lot entries and three clones. All entries were established in the greenhouse in April and transplanted to the field during the last week of May and the first week of June. Plant spacings were four feet by four feet. (See Figure 2) One row of border plants was used on all sides of the nursery. The experimental design was a randomized complete block with ten replications, each plot consisting of a single row of ten plants. Stand establishment was excellent with only four plants failing to survive during 1955 despite a shortage of moisture. Alfalfa was seeded among plants early in 1956 to prevent excessive spreading, supply nitrogen, control weeds, and offer uniform competition. An excellent stand of alfalfa was obtained, as illustrated in Figure 2.

All plots were evaluated on a row basis for fall vigor and relative greenness in October, 1955, for winter injury in May, 1956 and for aftermath vigor in August, 1956. Fall vigor and aftermath vigor was scored from 1 (least) to 10 (most) vegetative growth based on observations of height, density and spread. Fall greenness was scored from 1 (darkest green) to 10 (least green) based on the relative degree of leaf dying. Winter injury was scored from 1 (least) to 10 (most).

Individual plants in the nursery were evaluated for hay
vigor and bloom date over 10 replications and for leaf width and leafiness over five replications in June, 1956. Hay vigor was scored from 1 (least) to 10 (most). A plant was considered in bloom when the upper one-third of the florets on five panicles had anthers extruded. Leaf width was recorded as the average width in millimeters of the first leaf below the flag leaf measured on three culms per plant. Five panicles culms selected at random were used to sample leafiness on each plant and the ratio of leaf blade dry weight to total dry weight was used to determine leafiness percent.

Plant-to-plant variability in the space-planted nursery was studied by computing within-plot variances for: hay vigor score, bloom date, leaf width and percent leafiness. An estimate of genotypic variation for these agronomic characteristics was obtained by comparing within-plot variances for clones with that of the plants propagated from seed. Variation among members of a clone was considered to be environmental, whereas variation among plants arising from open-pollinated seed was considered a consequence of both genotypic and environmental effects. The genotypic variation for any trait was estimated according to the formula,

\[
\frac{s_p^2 - s_E^2}{s_p^2} \times 100,
\]

where \( s_p^2 \) was the grand mean within-plot variance for the seed
lots from open-pollinated seed and \( s^2_E \) was the mean within-plot variance for two of the clones.

Interrelationships among agronomic characters were investigated by calculations of simple correlation coefficients based on entry totals. Also, genotypic and phenotypic correlation coefficients were computed for certain characters by methods used by Burton (11) and Lebsock and Kalton (49). Seventeen selections were common to both the forage yield tests and the spaced nursery. Therefore, it was possible to compare the association of vigor scores in the spaced nursery with yields in the forage tests by computing correlation coefficients.

The seed shattering experiment, which was the last part of the investigation, was established in August, 1956, from selected plants vegetatively propagated in the greenhouse. Ten plants were selected for apparent shattering resistance and two for shattering susceptibility by observing plants in the space-planted nursery in 1956. Clonal members were transplanted into plots of five plants spaced two feet apart within rows and four feet between rows. A randomized complete block design with four replications was used.

In order to study seed shattering in this species it was necessary to consider the flowering habits. Different panicles on a single reed canarygrass plant may bloom over a period of several days and therefore, some panicles may have
completed anthesis while others on the same plant have not commenced blooming. Appearance of panicles at various stages of maturity is shown in Figure 3. Since seed shattering appeared dependent on bloom date, individual panicles were tagged when approximately the upper 1/3 of a panicle was in anthesis, as shown in Figure 4. Individual panicles were harvested beginning 15 days after bloom at three-day intervals. The panicles were threshed when air dry and the seed cleaned with a South Dakota Seed Blower using an air setting of 114. This removed everything except seeds containing caryopses. Seed yield per panicle was then determined by weighing to the nearest one-hundredth of a gram. Evaluations of shattering resistance were made by comparing mean seed yields per panicle at varying intervals of harvest with the initial yield 15 days after blooming.
Figure 3. Four panicles of reed canarygrass at different stages of development from prior to anthesis at left to completion of anthesis at right

Figure 4. The method used to identify the bloom date of panicles—individual culms tagged with date when upper 1/3 of panicle was in anthesis
EXPERIMENTAL RESULTS

In presenting results of the investigations, the following four main parts are considered separately: forage yield tests, seed yield tests, space-planted nursery and seed shattering experiment. Because of considerably more detail, information obtained from the space-planted nursery is subdivided into several different aspects for discussion purposes. They are agronomic performance, plant-to-plant variability, estimates of genotypic variation, intercharacter associations and planting method comparisons.

Forage Yield Tests

One objective of this study was to compare the various accessions for forage yielding ability with Ioreed and with bromegrass and orchardgrass. For this purpose tests were planted at Ames and Cresco in April, 1955. In the spring of 1956, stands of grass were estimated for all plots of these tests and these are presented in Table 2. Stands were generally fair at Ames and good at Cresco. Ph-59, a selection from Alabama, winterkilled and no data were taken on this entry; however, at Cresco, all plots seeded to this entry were used as a Ladino clover check. Reed canarygrass selections were generally not as vigorous as bromegrass and
Table 2. Mean agronomic performance of 18 reed canarygrass accessions compared with bromegrass and orchardgrass, in solid stands sown alone and with Ladino clover at Ames and Cresco in 1956 (yield expressed in tons per acre of oven-dry weight)

<table>
<thead>
<tr>
<th>Entry</th>
<th>Grass alone</th>
<th>Grass with Ladino clover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ames</td>
<td>Cresco</td>
</tr>
<tr>
<td></td>
<td>Stand (%)</td>
<td>Vigor score</td>
</tr>
<tr>
<td>Ph-11</td>
<td>66</td>
<td>3.4</td>
</tr>
<tr>
<td>Ph-13</td>
<td>36</td>
<td>5.4</td>
</tr>
<tr>
<td>Ph-21</td>
<td>48</td>
<td>5.4</td>
</tr>
<tr>
<td>Ph-38</td>
<td>84</td>
<td>2.2</td>
</tr>
<tr>
<td>Ph-39</td>
<td>56</td>
<td>3.8</td>
</tr>
<tr>
<td>Ph-40</td>
<td>76</td>
<td>3.0</td>
</tr>
<tr>
<td>Ph-49</td>
<td>68</td>
<td>4.6</td>
</tr>
<tr>
<td>Ph-50</td>
<td>84</td>
<td>2.2</td>
</tr>
<tr>
<td>Ph-51</td>
<td>74</td>
<td>4.2</td>
</tr>
<tr>
<td>Ph-54</td>
<td>58</td>
<td>5.0</td>
</tr>
<tr>
<td>Ph-55</td>
<td>74</td>
<td>3.8</td>
</tr>
<tr>
<td>Ph-56</td>
<td>64</td>
<td>3.4</td>
</tr>
<tr>
<td>Ph-57</td>
<td>72</td>
<td>3.0</td>
</tr>
<tr>
<td>Ph-58</td>
<td>62</td>
<td>5.0</td>
</tr>
<tr>
<td>Ph-59 (Ladino clover)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Ioreed-Syn. 2</td>
<td>48</td>
<td>3.8</td>
</tr>
<tr>
<td>Ioreed-Syn. 3</td>
<td>50</td>
<td>5.0</td>
</tr>
<tr>
<td>Ioreed-Syn. 4</td>
<td>60</td>
<td>4.6</td>
</tr>
<tr>
<td>Fisher bromegrass</td>
<td>90</td>
<td>1.0</td>
</tr>
<tr>
<td>Potomac orchardgrass</td>
<td>92</td>
<td>2.2</td>
</tr>
<tr>
<td>ME-11142 orchardgrass</td>
<td>98</td>
<td>3.0</td>
</tr>
<tr>
<td>Grand mean</td>
<td>68</td>
<td>3.7</td>
</tr>
</tbody>
</table>

*Ph-59 winter killed and was not included in calculations except as a Ladino clover entry at Cresco.*
orchardgrass in the spring of 1956 at Ames and there were only small differences among entries for spring vigor scores at Cresco.

All plots were clipped twice at Ames and three times at Cresco in 1956, and three times at both locations in 1957. Mean yield data for the two locations and years appear in Tables 2 and 3. Yields were low at Ames in 1956 because of below normal rainfall and were greater for fertilized stands of grass alone than for grass and Ladino clover mixtures. In 1957 at Ames, however, yield differences were small between the two methods of planting. Mean forage yields for combined years and for combined years and locations are summarized in Table 3. In many instances, yields of some reed canarygrass entries were as large or larger than for bromegrass or orchardgrass and there were yield differences among reed canarygrass entries. Reed canarygrass entries appeared superior to bromegrass and orchardgrass in aftermath growth as measured by second cutting yields at Ames in 1956 and 1957.

Separate analyses of variance were computed for each harvest except for the 1956 Ames test where no analyses were computed since some plots were not harvested because of poor stands. The test at Ames, although designed as a split-plot, was analysed as two individual randomized complete blocks in 1957. As shown in Table 4, mean yield differences among entries were significant (one percent level) for all cuttings
Table 3. Mean forage yields of 18 reed canarygrass accessions compared with bromegrass and orchardgrass in solid stands of grass sown alone and with Ladino clover at Ames and Cresco in 1957, together with combined yields for 1956 and 1957 (yield expressed in tons per acre of oven-dry weight)\textsuperscript{a}.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Annual yields, 1957</th>
<th>Combined yields, 1956-1957</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grass alone (Ames)</td>
<td>Grass with Ladino clover (Ames)</td>
</tr>
<tr>
<td></td>
<td>Grass alone (Cresco)</td>
<td>Grass with Ladino clover (Ames)</td>
</tr>
<tr>
<td>Ph-11</td>
<td>2.71</td>
<td>2.88</td>
</tr>
<tr>
<td>Ph-13</td>
<td>2.32</td>
<td>2.30</td>
</tr>
<tr>
<td>Ph-21</td>
<td>2.58</td>
<td>2.73</td>
</tr>
<tr>
<td>Ph-38</td>
<td>2.65</td>
<td>2.81</td>
</tr>
<tr>
<td>Ph-39</td>
<td>2.53</td>
<td>2.48</td>
</tr>
<tr>
<td>Ph-40</td>
<td>3.32</td>
<td>2.78</td>
</tr>
<tr>
<td>Ph-49</td>
<td>3.13</td>
<td>2.38</td>
</tr>
<tr>
<td>Ph-50</td>
<td>2.59</td>
<td>2.49</td>
</tr>
<tr>
<td>Ph-51</td>
<td>2.73</td>
<td>2.44</td>
</tr>
<tr>
<td>Ph-54</td>
<td>2.64</td>
<td>2.58</td>
</tr>
<tr>
<td>Ph-55</td>
<td>2.54</td>
<td>2.64</td>
</tr>
<tr>
<td>Ph-56</td>
<td>2.90</td>
<td>2.76</td>
</tr>
<tr>
<td>Ph-57</td>
<td>2.66</td>
<td>2.61</td>
</tr>
<tr>
<td>Ph-58</td>
<td>2.55</td>
<td>2.88</td>
</tr>
<tr>
<td>Ph-59 (Ladino clover)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Ireed-Syn. 2</td>
<td>2.58</td>
<td>2.64</td>
</tr>
<tr>
<td>Ireed-Syn. 3</td>
<td>2.87</td>
<td>2.83</td>
</tr>
<tr>
<td>Ireed-Syn. 4</td>
<td>2.43</td>
<td>2.52</td>
</tr>
<tr>
<td>Fisher bromegrass</td>
<td>2.60</td>
<td>2.08</td>
</tr>
<tr>
<td>Potomac orchardgrass</td>
<td>2.35</td>
<td>2.93</td>
</tr>
<tr>
<td>M2-11142 orchardgrass</td>
<td>2.76</td>
<td>2.69</td>
</tr>
<tr>
<td>Grand mean</td>
<td>2.67</td>
<td>2.62</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Ph-59 winter killed and was not included in calculations except as a Ladino clover entry at Cresco.
Table 4. Variance analyses for forage yields in solid stands of grass sown alone and with Ladino clover at Ames in 1957

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>First cutting</th>
<th>Second cutting</th>
<th>Third cutting</th>
<th>Annual yield</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sown alone</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replications</td>
<td>2</td>
<td>0.288</td>
<td>0.031**</td>
<td>0.047</td>
<td>0.278</td>
</tr>
<tr>
<td>Entries</td>
<td>19</td>
<td>0.039**</td>
<td>0.036**</td>
<td>0.014**</td>
<td>0.039**</td>
</tr>
<tr>
<td>Cuttings</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>10.516**</td>
</tr>
<tr>
<td>Entries x cuttings</td>
<td>38</td>
<td></td>
<td></td>
<td></td>
<td>0.025**</td>
</tr>
<tr>
<td>Replications x entries</td>
<td>38</td>
<td>0.014</td>
<td>0.011</td>
<td>0.004</td>
<td>0.017</td>
</tr>
<tr>
<td>Replications x cuttings</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>0.014</td>
</tr>
<tr>
<td>Reps. x entries x cuttings</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Coefficients of variation (%)</strong></td>
<td>9.7</td>
<td>20.6</td>
<td>13.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Grass with Ladino clover** |      |               |                |               |              |
| Replications        | 1    | 0.668         | 0.359          | 0.331*        | 1.323        |
| Entries             | 19   | 0.043         | 0.019          | 0.014*        | 0.022        |
| Cuttings            | 2    |               |                |               | 3.465**      |
| Entries x cuttings  | 38   |               |                |               | 0.027*       |
| Replications x entries | 19 | 0.024        | 0.013          | 0.005         | 0.016        |
| Replications x cuttings | 2  |               |                |               | 0.018        |
| Reps. x entries x cuttings | 38 |               |                |               | 0.013        |
| **Coefficients of variation (%)** | 14.5 | 20.2          | 12.7           |              |

*F value exceeds 5% level.
**F value exceeds 1% level.

and annual yield of grass grown alone. Only the third cutting of grass with Ladino clover exhibited significant (five percent level) differences at Ames. Mean yield differences at Cresco were significant for only the first cutting in 1956 and highly significant for the first cutting and annual yield
in 1957, as shown in Table 5. Significant interactions of entries x cuttings indicate that entries responded differently at the three harvests in both years. The relative size of coefficients of variation indicated the desirability of obtaining greater experimental accuracy in tests such as these with reed canarygrass.

In general, the accessions were quite similar in forage yield performance and since most of these accessions came from the North Central Region, they may represent a common ecotype. From the standpoint of selecting material for improvement, it is interesting to compare accessions from different sources with the commercial variety, Ioreed. As an example, the mean yield of Ph-40, from southwestern Minnesota, was larger than Ioreed synthetics in many comparisons (See Table 3). Several other accessions also compared favorably with Ioreed in forage yield. In stands of grass with Ladino clover, Ph-11 was higher yielding than Ioreed for combined years and locations. The three synthetic generations of Ioreed were similar in performance, though the Syn. 4 tended to be lowest in most instances. Apparently, from a genetic standpoint, no great differences exist among these accessions in forage yielding ability.
<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>1956 analyses</th>
<th>1957 analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First</td>
<td>Second</td>
</tr>
<tr>
<td>Replications</td>
<td>4</td>
<td>0.118</td>
<td>0.080</td>
</tr>
<tr>
<td>Entries</td>
<td>20</td>
<td>0.038*</td>
<td>0.012</td>
</tr>
<tr>
<td>Cuttings</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entries x cuttings</td>
<td>40</td>
<td>0.018**</td>
<td></td>
</tr>
<tr>
<td>Replications x entries</td>
<td>80a</td>
<td>0.019</td>
<td>0.012</td>
</tr>
<tr>
<td>Replications x cuttings</td>
<td>8</td>
<td>0.062</td>
<td></td>
</tr>
<tr>
<td>Reps. x entries x cuttings</td>
<td>160</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>Coefficients of variation (%)</td>
<td></td>
<td>16.9</td>
<td>16.2</td>
</tr>
<tr>
<td>Replications</td>
<td>4</td>
<td>0.236</td>
<td>0.396</td>
</tr>
<tr>
<td>Entries</td>
<td>20</td>
<td>0.063**</td>
<td>0.011</td>
</tr>
<tr>
<td>Cuttings</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entries x cuttings</td>
<td>40</td>
<td>0.022**</td>
<td></td>
</tr>
<tr>
<td>Replications x entries</td>
<td>80</td>
<td>0.014</td>
<td>0.016</td>
</tr>
<tr>
<td>Replications x cuttings</td>
<td>8</td>
<td>0.263</td>
<td></td>
</tr>
<tr>
<td>Reps. x entries x cuttings</td>
<td>160</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>Years</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replications x years</td>
<td>4</td>
<td>0.065</td>
<td></td>
</tr>
<tr>
<td>Entries x years</td>
<td>20</td>
<td>0.043</td>
<td></td>
</tr>
<tr>
<td>Reps. x entries x years</td>
<td>80</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td>Coefficients of variation (%)</td>
<td></td>
<td>23.0</td>
<td>17.5</td>
</tr>
</tbody>
</table>

*aOne missing plot in second and third cutting.

*F value exceeds 5% level.

**F value exceeds 1% level.
Seed Yield Tests

To gain information on possible variation among accessions in seed producing ability, 27 seed lots were studied in seed yield tests at the same locations during 1956 and 1957. Data were obtained on panicle production, seed yield and germination capacity. Panicle production, one of the components of seed yield, was scored from 1 (least) to 5 (most) on a row basis in 1956 and panicles per three-foot section of row were counted in 1957. Many of the accessions produced more panicles than Ioreed, as shown in Table 6. Germination percentages based on a composite of harvested seed from five replications of each entry in 1956 at Cresco were very high (See Table 6) and no differences among entries were apparent.

In order to study variation for seed production, seed yields were measured in pounds per acre for each year and location. Mean seed yields for two years at each location and for years and locations combined are summarized in Table 7. The reed canarygrass accessions, especially Ph-2 through Ph-23 which were selected for apparent resistance to seed shattering, were generally superior to the Ioreed synthetics in seed production.

Separate analyses of variance were computed for panicle production measurements and for each seed harvest except the
Table 6. Mean panicle production and germination percentages for 27 reed canarygrass accessions at Ames and Cresco in 1956 and 1957

<table>
<thead>
<tr>
<th>Entry</th>
<th>Panicle production score - 1956</th>
<th>Panicle count 1957</th>
<th>Germination (%) 1956</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph- 2</td>
<td>3.8</td>
<td>3.2</td>
<td>188</td>
</tr>
<tr>
<td>Ph- 6</td>
<td>3.5</td>
<td>2.8</td>
<td>163</td>
</tr>
<tr>
<td>Ph- 9</td>
<td>4.3</td>
<td>2.8</td>
<td>177</td>
</tr>
<tr>
<td>Ph-10</td>
<td>3.5</td>
<td>2.6</td>
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</tr>
<tr>
<td>Ph-11</td>
<td>3.0</td>
<td>3.2</td>
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</tr>
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<td>Ph-13</td>
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<td>Ph-49</td>
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<td>3.0</td>
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<td>2.0</td>
<td>163</td>
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<td>Ph-57</td>
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<td>3.2</td>
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<tr>
<td>Ph-58</td>
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<td>168</td>
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<tr>
<td>Ioreed-</td>
<td>Syn. 2</td>
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<td>136</td>
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<td>Syn. 3</td>
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<td>124</td>
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<tr>
<td>Syn. 4</td>
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<td>2.2</td>
<td>179</td>
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<tr>
<td>Grand mean</td>
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<td>3.0</td>
<td>168</td>
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Table 7. Two-year mean seed yields and rank of 27 reed canarygrass accessions at Ames and Cresco (yields expressed in pounds per acre)

<table>
<thead>
<tr>
<th>Entry</th>
<th>Ames Yield</th>
<th>Ames Rank</th>
<th>Cresco Yield</th>
<th>Cresco Rank</th>
<th>Combined locations Yield</th>
<th>Combined locations Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph- 2</td>
<td>225.7</td>
<td>5</td>
<td>115.5</td>
<td>9</td>
<td>170.6</td>
<td>7</td>
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<tr>
<td>Ph- 6</td>
<td>212.0</td>
<td>3</td>
<td>101.2</td>
<td>19</td>
<td>171.6</td>
<td>6</td>
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<tr>
<td>Ph- 9</td>
<td>--</td>
<td>-</td>
<td>104.5</td>
<td>17</td>
<td>--</td>
<td>-</td>
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<tr>
<td>Ph-10</td>
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<td>108.0</td>
<td>14</td>
<td>173.6</td>
<td>4</td>
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<tr>
<td>Ph-11</td>
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<td>12</td>
<td>162.6</td>
<td>10</td>
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<tr>
<td>Ph-13</td>
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<tr>
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<td>143.8</td>
<td>1</td>
<td>201.4</td>
<td>1</td>
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<tr>
<td>Ph-16</td>
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<td>-</td>
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<td>24</td>
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<td>-</td>
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<tr>
<td>Ph-21</td>
<td>221.6</td>
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<td>3</td>
<td>175.8</td>
<td>3</td>
</tr>
<tr>
<td>Ph-23</td>
<td>208.9</td>
<td>12</td>
<td>122.0</td>
<td>5</td>
<td>165.4</td>
<td>8</td>
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<tr>
<td>Ph-38</td>
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<td>12</td>
<td>161.2</td>
<td>12</td>
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<tr>
<td>Ph-39</td>
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<tr>
<td>Ph-40</td>
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<td>127.2</td>
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<td>5</td>
</tr>
<tr>
<td>Ph-43</td>
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<td>137.4</td>
<td>21</td>
</tr>
<tr>
<td>Ph-49</td>
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<td>15</td>
<td>92.4</td>
<td>21</td>
<td>145.8</td>
<td>19</td>
</tr>
<tr>
<td>Ph-50</td>
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<td>97.8</td>
<td>20</td>
<td>135.1</td>
<td>22</td>
</tr>
<tr>
<td>Ph-51</td>
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<td>14</td>
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<tr>
<td>Ph-54</td>
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<td>87.8</td>
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</tr>
<tr>
<td>Ph-55</td>
<td>198.3</td>
<td>16</td>
<td>110.5</td>
<td>11</td>
<td>154.4</td>
<td>15</td>
</tr>
<tr>
<td>Ph-56</td>
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<td>18</td>
<td>107.8</td>
<td>15</td>
<td>153.0</td>
<td>17</td>
</tr>
<tr>
<td>Ph-57</td>
<td>217.1</td>
<td>8</td>
<td>107.2</td>
<td>16</td>
<td>162.2</td>
<td>11</td>
</tr>
<tr>
<td>Ph-58</td>
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<td>13</td>
<td>104.4</td>
<td>18</td>
<td>156.2</td>
<td>14</td>
</tr>
<tr>
<td>Ioreed-Syn.2</td>
<td>169.0</td>
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<td>73.4</td>
<td>26</td>
<td>121.2</td>
<td>24</td>
</tr>
<tr>
<td>Ioreed-Syn.3</td>
<td>182.0</td>
<td>21</td>
<td>77.7</td>
<td>25</td>
<td>129.8</td>
<td>23</td>
</tr>
<tr>
<td>Ioreed-Syn.4</td>
<td>161.3</td>
<td>25</td>
<td>61.1</td>
<td>27</td>
<td>111.2</td>
<td>25</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>206.0</td>
<td></td>
<td>106.2</td>
<td></td>
<td>156.1</td>
<td></td>
</tr>
</tbody>
</table>

Note: Ph- stands for Phaseolus vulgaris, while Ioreed-Syn. denotes Ioreed synthetic.
1956 results at Ames where some data were omitted because of poor stands. Mean panicle production score differences were not significant at Cresco in 1956. However, mean panicle count differences were significant at the five and one percent level at Ames and Cresco, respectively, in 1957. Mean seed yield differences were statistically significant in all cases, as noted in Table 8. Coefficients of variation were large for the seed yield experiments, indicating relatively large interactions of replications x entries. Part of this variability was due to differential shattering among entries before plots were harvested.

An insight into the performance of accessions at different locations was derived from an analysis of variance of combined location data. Seed yield data from Cresco and Ames in 1957 were combined and the analysis of variance is presented in Table 9. In this case the entries x locations interaction was not significant even though yield differences for entries were significant at the one percent level. The ranking of entries was relatively consistent at both locations for seed yield. Pht-14 and Pht-18 were first and second, respectively, and the Ioreed synthetics were low or lowest for seed yield at both locations. These results indicate that genetic differences exist among these collections for seed productivity even though the collections are quite similar for forage yield.
Table 8. Variance analyses for seed yields and panicle production for 27 accessions at Cresco in 1956, and Ames and Cresco in 1957

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>Ames Seed yield</th>
<th>Ames Panicle production</th>
<th>Cresco Seed yield</th>
<th>Cresco Panicle production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2,371.7</td>
<td>12.80</td>
<td>203.6**</td>
<td>1.27</td>
</tr>
<tr>
<td>Replications</td>
<td>4</td>
<td>2,371.7</td>
<td>12.80</td>
<td>203.6**</td>
<td>1.27</td>
</tr>
<tr>
<td>Entries</td>
<td>26</td>
<td>203.6**</td>
<td>1.27</td>
<td>84.9</td>
<td>0.99</td>
</tr>
<tr>
<td>Error</td>
<td>104</td>
<td>84.9</td>
<td>0.99</td>
<td>84.9</td>
<td>0.99</td>
</tr>
<tr>
<td>Coefficients of variation (%)</td>
<td></td>
<td>36.7</td>
<td>32.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1957 analyses

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>Mean squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replications</td>
<td>4</td>
<td>981.1</td>
</tr>
<tr>
<td>Entries</td>
<td>25, 25, 26, 26</td>
<td>1,392.7*</td>
</tr>
<tr>
<td>Error</td>
<td>103, 103, 104, 104</td>
<td>628.8</td>
</tr>
<tr>
<td>Coefficients of variation (%)</td>
<td></td>
<td>16.4</td>
</tr>
</tbody>
</table>

*F value exceeds 5% level.
**F value exceeds 1% level.

Table 9. Variance analysis of seed yields for Ames and Cresco combined in 1957

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>Mean squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locations</td>
<td>1</td>
<td>535,557.9**</td>
</tr>
<tr>
<td>Replications within locations</td>
<td>8</td>
<td>1,711.2</td>
</tr>
<tr>
<td>Entries</td>
<td>26</td>
<td>1,505.7**</td>
</tr>
<tr>
<td>Entries x locations</td>
<td>26</td>
<td>538.6</td>
</tr>
<tr>
<td>Entries x replications within locations</td>
<td>207</td>
<td>398.1</td>
</tr>
</tbody>
</table>

**F value exceeds 1% level.
An indication of the association of panicle production with seed yield was obtained by calculating correlation coefficients for panicle production with seed yield. These correlations are given in Table 10 and are significant except for Ames data in 1957. Apparently, panicle production scores were as indicative of seed yields as actual panicle counts in this study.

Table 10. Associations between mean panicle production and mean seed yield of 27 reed canarygrass selections at Ames and Cresco in 1956 and 1957, as measured by simple correlation coefficients

<table>
<thead>
<tr>
<th>Characters correlated</th>
<th>D.F.</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panicle production score and:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>seed yield at Ames, Iowa, 1956</td>
<td>23</td>
<td>0.32**</td>
</tr>
<tr>
<td>seed yield at Cresco, Iowa, 1956</td>
<td>25</td>
<td>0.72**</td>
</tr>
<tr>
<td>Panicle production count and:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>seed yield at Ames, Iowa, 1957</td>
<td>25</td>
<td>0.27**</td>
</tr>
<tr>
<td>seed yield at Cresco, Iowa, 1957</td>
<td>25</td>
<td>0.71**</td>
</tr>
</tbody>
</table>

**Exceeds 1% level.

Space-planted Nursery

The third main part of this investigation was a study of individual plants of 39 seed lots and propagules of three clones in a space-planted nursery. The nursery consisted of ten replications with ten plants per plot and entries were
evaluated for the following: fall vigor, greenness, winter injury and aftermath vigor on a plot basis, and hay vigor, bloom date, leaf width and percent leafiness on an individual plant basis.

**Agronomic performance**

The agronomic performance of all entries for these characteristics was studied to provide information concerning differences among the accessions and also to compare accessions from various sources with the Ioreed synthetics and the three clones.

Mean performance based on plot observations noted in 1955 and 1956 is summarized in Table 11. Two of the clones, I-1 and R-5, appeared superior for fall vigor, intermediate for fall greenness and aftermath growth and below average in winter injury. Accessions Ph-59 and Ph-66 from Alabama and Arkansas, respectively, and the clone from Superior (S-1) were severely winter injured. Mean fall vigor and aftermath vigor scores varied considerably among the three Ioreed synthetic strains; however, many accessions appeared as good or better than Ioreed for these characteristics. Ioreed showed more winter injury than many other accessions.

Mean agronomic performance based on individual plant data is summarized in Table 12. Hay vigor scores and bloom date were noted over ten replications and leaf width and
Table 11. Mean performance for four agronomic characters of 39 seed accessions and three clones in the space-planted nursery in 1955 and 1956 at Ames. (Data taken on a plot basis over 10 replications)

<table>
<thead>
<tr>
<th>Entries</th>
<th>Fall vigor</th>
<th>Greenness</th>
<th>Winter injury</th>
<th>Aftermath vigor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td>Rank</td>
<td>Score</td>
<td>Rank</td>
</tr>
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<td>5.8</td>
<td>27</td>
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<td>14</td>
<td>6.6</td>
<td>40</td>
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<tr>
<td>Ph-4</td>
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<td>37</td>
<td>6.6</td>
<td>40</td>
</tr>
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<td>Ph-5</td>
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<td>6.2</td>
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<td>Ph-6</td>
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<td>Ph-8</td>
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<td>Ph-10</td>
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<td>27</td>
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<td>1956 Aftermath vigor</td>
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</tr>
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<td>-------------------</td>
<td>---------------------</td>
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</tr>
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<td>Rank</td>
<td>Score</td>
<td>Rank</td>
</tr>
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<td>15</td>
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<td>6.0</td>
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<td>5</td>
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<td>13</td>
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<td>Ph-56</td>
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<td>1-9</td>
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**Clones**

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<td>3.2</td>
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<td>L.S.D.(1% level)</td>
<td>0.68</td>
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<td>1.07</td>
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Table 12. Mean performance for four agronomic characters of 37 seed accessions and two clones in the space-planted nursery in 1956 at Ames (Data taken on an individual plant basis)

<table>
<thead>
<tr>
<th>Seed accessions</th>
<th>Hay vigor Score</th>
<th>Hay vigor Rank</th>
<th>Bloom date (June)</th>
<th>Bloom date Rank</th>
<th>Leaf width (mm.)</th>
<th>Leaf width Rank</th>
<th>Leafiness (%)</th>
<th>Leafiness Rank</th>
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</thead>
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<td>Ph-2</td>
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<td>7</td>
<td>5.4</td>
<td>3</td>
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<td>7.8</td>
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<td>10</td>
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<td>15</td>
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<td>28</td>
<td>27.9</td>
<td>16</td>
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</tbody>
</table>

*Hay vigor scores and bloom date taken over ten replications--leaf width and percent leafiness measured over five replications.
Table 12. (Continued)

<table>
<thead>
<tr>
<th>Entries</th>
<th>Hay vigor Score</th>
<th>Bloom date (June) 4.5</th>
<th>Leaf width (mm.) 16.0</th>
<th>Leafiness % Rank</th>
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<td>27.1</td>
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<td>28.3</td>
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<td>Ph-64</td>
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<td>6.2</td>
<td>15.62</td>
<td>27.81</td>
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<td>18-47</td>
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<td></td>
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<td>4</td>
<td>3.9</td>
<td>26.9</td>
</tr>
<tr>
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<td>1</td>
<td>6.9</td>
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<td>5.4</td>
<td>16.4</td>
<td>25.1</td>
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<td>L.S.D.(1% level)</td>
<td>0.50</td>
<td>1.65</td>
<td>1.41</td>
<td>2.56</td>
</tr>
</tbody>
</table>
leafiness percentage over five replications. No data were taken concerning these characteristics on Ph-59, Ph-66 and S-1 because of severe winter injury. Many of the seed accessions and clones I-1 and R-5 appeared superior to the Ioreed strains for hay vigor. There was considerable variation among entries for hay vigor, bloom date and leafiness percentage as shown in Table 12. Ranges for bloom date and leafiness on individual plants were from June 1 to June 16 and from 18 to 47 percent, respectively. Range for leaf width was from 9 to 25 millimeters.

Variance analyses for fall vigor, greenness, winter injury and aftermath vigor scores are presented in Table 13. Differences among entries were highly significant for all four characteristics. Differences among entries were also highly significant for hay vigor score, bloom date and leafiness as shown in Table 14. However, leaf width differences among entries were only significant at the five percent level. Least significant differences calculated at the one percent level for these eight characteristics are presented at the bottom of Tables 11 and 12 to indicate true differences between any two entry means chosen at random.

It would seem from the results presented thus far that a strain of reed canarygrass either earlier or later maturing than Ioreed could be developed and also that improvement over Ioreed would be possible for: fall vigor, hay vigor, winter
Table 13. Variance analyses for four agronomic characters for 39 seed accessions and three clones in the space-planted nursery (Data on a plot mean basis)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>Fall vigor score</th>
<th>Greenness score</th>
<th>Winter injury score</th>
<th>Aftermath vigor score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replications</td>
<td>9</td>
<td>2.42</td>
<td>2.48</td>
<td>11.47</td>
<td>2.80</td>
</tr>
<tr>
<td>Entries</td>
<td>41</td>
<td>8.26**</td>
<td>12.36**</td>
<td>25.86**</td>
<td>9.23**</td>
</tr>
<tr>
<td>Among seedling entries</td>
<td>38</td>
<td>7.34**</td>
<td>10.57**</td>
<td>21.66**</td>
<td>8.15**</td>
</tr>
<tr>
<td>Among clones</td>
<td>2</td>
<td>4.64**</td>
<td>26.54**</td>
<td>75.44**</td>
<td>26.13**</td>
</tr>
<tr>
<td>Seedlings vs. clones</td>
<td>1</td>
<td>50.47**</td>
<td>52.22**</td>
<td>86.09**</td>
<td>16.59**</td>
</tr>
<tr>
<td>Entries x replications</td>
<td>369</td>
<td>0.34</td>
<td>1.04</td>
<td>0.86</td>
<td>0.43</td>
</tr>
</tbody>
</table>

**F value exceeds 1% level.
Table 14. Variance analyses for four agronomic characters for 37 seed accessions and two clones in the space-planted nursery (Data on plot mean basis)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>Hay vigor score</th>
<th>Mean squares</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bloom date</td>
</tr>
<tr>
<td>Replications</td>
<td>9</td>
<td>0.99</td>
<td>21.10</td>
</tr>
<tr>
<td>Entries</td>
<td>38</td>
<td>2.25**</td>
<td>16.63**</td>
</tr>
<tr>
<td>Among seedling entries</td>
<td>36</td>
<td>2.10**</td>
<td>16.00**</td>
</tr>
<tr>
<td>Between clones</td>
<td>1</td>
<td>0.42**</td>
<td>45.00**</td>
</tr>
<tr>
<td>Seedlings vs. clones</td>
<td>1</td>
<td>9.53**</td>
<td>10.94**</td>
</tr>
<tr>
<td>Entries x replications</td>
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<td>0.18</td>
<td>1.01</td>
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<tr>
<td>Replications</td>
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<td>1.88</td>
<td>125.65</td>
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<tr>
<td>Entries</td>
<td>38</td>
<td>2.72*</td>
<td>7.88**</td>
</tr>
<tr>
<td>Among seedling entries</td>
<td>36</td>
<td>2.68*</td>
<td>5.17**</td>
</tr>
<tr>
<td>Between clones</td>
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<td>32.69**</td>
</tr>
<tr>
<td>Seedlings vs. clones</td>
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<td>6.27</td>
<td>69.75**</td>
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<tr>
<td>Entries x replications</td>
<td>194</td>
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<td>2.41</td>
</tr>
</tbody>
</table>

*F value exceeds the 5% level.
**F value exceeds the 1% level.
survival, and leafiness. However, a more reliable estimate of the change possible by selection may be derived by studying plant-to-plant variation.

**Plant-to-plant variability.**

In order to estimate the variability present within reed canarygrass, individual plant measurements were used to study plant-to-plant variation. Variances among plants within plots were computed for hay vigor, bloom date, leaf width and leafiness percentage. Hay vigor and bloom date data were based on ten replications and leaf width and leafiness on five replications. A summary of these average within-plot variances for each of the 39 entries appears in Table 15.

Variance analyses of the within-plot variances for seed accessions are presented in Table 16. Seed accessions did not differ significantly in mean within-plot variances for any of the four characteristics studied. Thus, there was a similarity in degree of variability among the seed accessions. Mean within-plot variances for the two clones were considerably less, on the other hand, than seed accessions for bloom date, leaf width and leafiness percentage and moderately less for hay vigor. This lower variability for vegetatively propagated clones is expected since presumably clonal members are genetically identical and plants arising from open-pollinated seeds may be genetically quite different.
Table 15. Mean within-plot variances for four characters observed on 37 seed accessions and two clones

<table>
<thead>
<tr>
<th>Entries</th>
<th>Hay vigor score</th>
<th>Bloom date (June)</th>
<th>Leaf width (millimeters)</th>
<th>Leafiness (%)</th>
</tr>
</thead>
<tbody>
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<td><strong>Seed accessions</strong></td>
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<td></td>
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<td>4.78</td>
<td>10.39</td>
</tr>
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<td>5.01</td>
<td>6.48</td>
<td>11.97</td>
</tr>
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<td>4.18</td>
<td>3.11</td>
<td>14.87</td>
</tr>
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<td>4.32</td>
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<tr>
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<td>19.20</td>
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<td>5.17</td>
<td>8.09</td>
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<td>4.27</td>
<td>5.72</td>
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<td>7.03</td>
<td>6.44</td>
<td>9.60</td>
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<td>8.53</td>
<td>2.39</td>
<td>6.76</td>
</tr>
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<td>1.19</td>
<td>6.42</td>
<td>3.77</td>
<td>7.91</td>
</tr>
<tr>
<td>Ph-23</td>
<td>1.07</td>
<td>5.99</td>
<td>3.64</td>
<td>9.48</td>
</tr>
<tr>
<td>Ph-30</td>
<td>1.03</td>
<td>5.22</td>
<td>2.82</td>
<td>9.86</td>
</tr>
<tr>
<td>Ph-33</td>
<td>1.06</td>
<td>6.93</td>
<td>5.04</td>
<td>8.57</td>
</tr>
<tr>
<td>Ph-38</td>
<td>0.68</td>
<td>6.03</td>
<td>3.02</td>
<td>8.75</td>
</tr>
<tr>
<td>Ph-39</td>
<td>0.69</td>
<td>6.47</td>
<td>3.64</td>
<td>9.25</td>
</tr>
<tr>
<td>Ph-40</td>
<td>0.99</td>
<td>6.81</td>
<td>4.06</td>
<td>12.47</td>
</tr>
<tr>
<td>Ph-43</td>
<td>0.82</td>
<td>5.82</td>
<td>4.28</td>
<td>10.00</td>
</tr>
<tr>
<td>Ph-44</td>
<td>0.82</td>
<td>5.30</td>
<td>4.89</td>
<td>9.69</td>
</tr>
<tr>
<td>Ph-49</td>
<td>0.74</td>
<td>7.69</td>
<td>4.08</td>
<td>13.71</td>
</tr>
<tr>
<td>Ph-50</td>
<td>0.65</td>
<td>5.04</td>
<td>4.46</td>
<td>9.97</td>
</tr>
<tr>
<td>Ph-51</td>
<td>1.00</td>
<td>6.10</td>
<td>3.47</td>
<td>7.14</td>
</tr>
<tr>
<td>Ph-53</td>
<td>0.90</td>
<td>4.12</td>
<td>4.82</td>
<td>13.99</td>
</tr>
<tr>
<td>Ph-54</td>
<td>0.76</td>
<td>5.77</td>
<td>3.21</td>
<td>7.08</td>
</tr>
<tr>
<td>Ph-55</td>
<td>0.63</td>
<td>6.69</td>
<td>3.08</td>
<td>9.81</td>
</tr>
<tr>
<td>Ph-56</td>
<td>0.58</td>
<td>7.56</td>
<td>3.80</td>
<td>14.51</td>
</tr>
<tr>
<td>Ph-57</td>
<td>0.87</td>
<td>9.18</td>
<td>3.79</td>
<td>12.90</td>
</tr>
<tr>
<td>Ph-58</td>
<td>0.72</td>
<td>7.12</td>
<td>4.02</td>
<td>9.58</td>
</tr>
<tr>
<td>Ph-64</td>
<td>1.24</td>
<td>7.28</td>
<td>6.17</td>
<td>8.43</td>
</tr>
<tr>
<td>Ioreed - Syn 2</td>
<td>0.99</td>
<td>5.86</td>
<td>3.25</td>
<td>7.45</td>
</tr>
<tr>
<td>Ioreed - Syn 3</td>
<td>0.83</td>
<td>4.77</td>
<td>3.86</td>
<td>10.03</td>
</tr>
<tr>
<td>Ioreed - Syn 4</td>
<td>1.04</td>
<td>5.41</td>
<td>4.43</td>
<td>6.84</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.97</td>
<td>6.26</td>
<td>4.35</td>
<td>10.53</td>
</tr>
<tr>
<td><strong>Clones</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-1</td>
<td>0.84</td>
<td>3.83</td>
<td>1.41</td>
<td>4.00</td>
</tr>
<tr>
<td>R-5</td>
<td>0.60</td>
<td>2.74</td>
<td>1.54</td>
<td>1.68</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.72</td>
<td>3.28</td>
<td>1.48</td>
<td>2.84</td>
</tr>
</tbody>
</table>
Table 16. Variance analyses of within-plot variances for four agronomic characteristics

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>Mean squares</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hay vigor</td>
<td>Bloom date</td>
<td></td>
</tr>
<tr>
<td>Replications</td>
<td>9</td>
<td>4.09**</td>
<td>47.13**</td>
<td></td>
</tr>
<tr>
<td>Entries</td>
<td>36</td>
<td>0.59</td>
<td>11.68</td>
<td></td>
</tr>
<tr>
<td>Replications x entries</td>
<td>324</td>
<td>0.45</td>
<td>8.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leaf width</td>
<td>Leafiness</td>
<td></td>
</tr>
<tr>
<td>Replications</td>
<td>1</td>
<td>1.41</td>
<td>57.86</td>
<td></td>
</tr>
<tr>
<td>Entries</td>
<td>36</td>
<td>5.44</td>
<td>45.31</td>
<td></td>
</tr>
<tr>
<td>Replications x entries</td>
<td>144</td>
<td>6.05</td>
<td>39.86</td>
<td></td>
</tr>
</tbody>
</table>

**F value exceeds 1% level.

Estimates of genotypic variability

Selection within a population can be successful only to the extent that variability is genotypic in nature even though total (phenotypic) variability may be large. The variances computed in the previous section, concerning relative plant-to-plant variability, were used to estimate the average extent of genotypic variability in the population of plants arising from open-pollinated seed. Variation among plants of the seed-lot entries was considered to be both genotypic and environmental in nature, whereas variation among members of a clone was attributed to environmental effects. Estimates of the extent of genotypic variation were obtained by subtracting the mean clonal variance from the mean variance of all seedling entries and expressing the difference as a percentage of the mean variance of the seedling entries (See Table 17).
Table 17. Mean estimates of genotypic variation exhibited by 37 seed progenies of reed canarygrass for four characteristics

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Hay vigor (June)</th>
<th>Bloom date</th>
<th>Leaf width</th>
<th>Leafiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed accessions</td>
<td>( s^2_p )</td>
<td>0.97</td>
<td>6.26</td>
<td>4.35</td>
<td>10.53</td>
</tr>
<tr>
<td>Clones</td>
<td>( s^2_E )</td>
<td>0.72</td>
<td>3.28</td>
<td>1.48</td>
<td>2.94</td>
</tr>
<tr>
<td>Difference</td>
<td>( s^2_G )</td>
<td>0.25</td>
<td>2.98</td>
<td>2.37</td>
<td>7.69</td>
</tr>
</tbody>
</table>

Genotypic variation (%) \( \left( \frac{s^2_G}{s^2_p} \times 100 \right) \) 25.8 47.6 66.0 73.1

Estimates of percent genotypic variation were high for leaf width and leafiness, indicating that variation in these characters was largely genotypic. Slightly over half of the total variation in bloom date and approximately 74 percent of the total variation in hay vigor could be attributed to environmental effects. It is necessary to point out that these estimates of genotypic variances are probably maximum values in the sense that they include additive genetic variance, variance due to dominance deviations, variance due to epistasis and deviations due to genotype x environmental interactions. The high estimates of genotypic variation calculated for percent leafiness, leaf width and bloom date indicate that some genetic advance may be possible by selection among the spaced plants included in this experiment.
Intercharacter relationships

The degree of association among certain agronomic characters is of importance to a breeding program since such relationships indicate possibilities for obtaining combinations of these characters in selected material. Since leafiness percentage may affect forage quality in reed canarygrass, its interrelationships with other characters should be of value. Association between leafiness and other agronomic traits were determined by the calculation of simple correlation coefficients which are presented in Table 18. Leafiness appeared to be unrelated to hay vigor and leaf width in this study. However, leafiness was negatively correlated with bloom date. This negative correlation between leafiness and bloom date may have been partially due to some loss of seed from the earlier blooming plants at the time of sampling.

Simple correlations may approach the total relationships that exist among various character; however, the extent to which characters are genotypically associated would be of more significance from a selection standpoint. The method used to obtain a measure of genotypic association involved analyses of variance and covariance of single plant data for leafiness, hay vigor, bloom date and leaf width. Data were used from 37 seed accessions and two clones from five replications. Consequently, considering missing plants, data from 1,729 plants arising from open-pollinated seed were used to
Table 18. Associations between leafiness percentage and other agronomic characters observed in the space-planted nursery, as measured by simple correlation coefficients

<table>
<thead>
<tr>
<th>Characters correlated</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leafiness and:</td>
<td></td>
</tr>
<tr>
<td>Hay vigor</td>
<td>-0.15</td>
</tr>
<tr>
<td>Bloom date</td>
<td>-0.42**</td>
</tr>
<tr>
<td>Leaf width</td>
<td>0.18</td>
</tr>
</tbody>
</table>

*aAll comparisons involve 35 D. F.

**Exceeds 1% level.

calculate phenotypic values and 100 clonal members were used to measure environmental effects. Covariances between characters in clonal populations and in the seed progenies were used to estimate environmental and phenotypic relationships, respectively. Differences between these two covariances for pairs of characteristics were considered estimates of genotypic covariances. Correlation coefficients were obtained by dividing each covariance by the geometric mean of the appropriate variances. The variance and covariance values used in this study are presented in Table 19, and the resulting correlation coefficients are shown in Table 20.

Phenotypic correlation coefficients were small in all cases. The negative correlations between leafiness and hay
Table 19. Variance and covariance values used to calculate phenotypic, environmental and genotypic correlations involving leafiness, hay vigor, bloom date and leaf width

<table>
<thead>
<tr>
<th>Characters</th>
<th>Components</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phenotypic</td>
<td>Environmental</td>
<td>Genotypic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Variances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leafiness</td>
<td>14.95</td>
<td>11.14</td>
<td>3.80</td>
<td></td>
</tr>
<tr>
<td>Hay vigor</td>
<td>1.39</td>
<td>1.08</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>Bloom date</td>
<td>9.13</td>
<td>8.46</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>Leaf width</td>
<td>4.87</td>
<td>2.23</td>
<td>2.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Covariances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leafiness and:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay vigor</td>
<td>-0.68</td>
<td>-1.31</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>Bloom date</td>
<td>-0.19</td>
<td>-5.52</td>
<td>5.32</td>
<td></td>
</tr>
<tr>
<td>Leaf width</td>
<td>-1.03</td>
<td>-1.50</td>
<td>0.47</td>
<td></td>
</tr>
</tbody>
</table>

Table 20. Phenotypic, environmental and genotypic correlation coefficients for association of leafiness with hay vigor, bloom date and leaf width

<table>
<thead>
<tr>
<th>Characters correlated</th>
<th>Correlation coefficients</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phenotypic</td>
<td>Environmental</td>
<td>Genotypic</td>
<td></td>
</tr>
<tr>
<td>Leafiness and:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay vigor</td>
<td>-0.15**</td>
<td>-0.38**</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>Bloom date</td>
<td>-0.02</td>
<td>-0.57**</td>
<td>3.34</td>
<td></td>
</tr>
<tr>
<td>Leaf width</td>
<td>-0.12**</td>
<td>-0.30**</td>
<td>0.15</td>
<td></td>
</tr>
</tbody>
</table>

**Exceeds 1% level.

vigor and leafiness and leaf width were highly significant since 1,727 degrees of freedom were used for testing. Environmental correlations, on the other hand, were negative and highly significant for all three values when tested using 98 degrees of freedom.
All genotypic correlations were positive since the environmental covariances were of greater negative magnitude than phenotypic covariances. The genotypic correlation value found between leafiness and bloom date was unrealistic since theoretically a correlation cannot exceed unity. There was a positive genotypic association between leafiness and hay vigor and essentially no genotypic relationship between leafiness and leaf width.

**Planting method comparisons**

Reed canarygrass is generally grown in solid stands commercially, but selection by plant breeders is commonly practiced on plants in space-planted nurseries. If these procedures are followed, there should be a substantial positive relationship between the two planting methods for desirable characters if selection for desirability among spaced plants is to be effective toward improving performance in solid stands.

Associations between vigor scores in the space-planted nursery and actual forage yields in solid stands were determined by calculating simple correlation coefficients. Data from 17 reed canarygrass accessions common to the space-planted nursery and the forage yield test at Ames were used in this study. Correlations between mean hay vigor scores and mean first cutting or annual yields for both the first
and second year after establishment were low and not significant, as shown in Table 21. Also, mean aftermath vigor scores were not associated with mean second or third cutting yields. This lack of relationship between methods of planting for these characteristics indicates that spaced-plants of reed canarygrass selected as high in hay and aftermath vigor scores may not result in improved forage yield or aftermath growth in solid stands.

Seed Shattering Experiment

The final part of this investigation was a study of seed shattering in reed canarygrass. Information concerning the variability within this species for seed shattering would be of value in breeding for resistance to this characteristic. In attempting to measure seed shattering differences independent of date of flowering, individual panicles of 12 vegetatively-propagated clones were identified as to date of bloom by tagging. Harvests were then made relative to bloom date. The number of panicles sampled and mean grams of seed per panicle harvested from these selections at five-day intervals beginning 15 days after bloom are presented in Table 22. Panicles of most selections commenced losing seed approximately 15 days after blooming except for Entry 4. This clone started shattering slightly about 20 days after flowering.
Table 21. Associations between vigor scores in the space-planted nursery and forage yield in solid stands for 17 reed canarygrass accessions

<table>
<thead>
<tr>
<th>Characters correlated</th>
<th>Correlation coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay vigor and:</td>
<td></td>
</tr>
<tr>
<td>First cutting - first year</td>
<td>0.08</td>
</tr>
<tr>
<td>Annual yield - first year</td>
<td>0.17</td>
</tr>
<tr>
<td>First cutting - second year</td>
<td>0.01</td>
</tr>
<tr>
<td>Annual yield - second year</td>
<td>0.21</td>
</tr>
<tr>
<td>Aftermath vigor and:</td>
<td></td>
</tr>
<tr>
<td>Second cutting - first year</td>
<td>0.10</td>
</tr>
<tr>
<td>Second cutting - second year</td>
<td>0.07</td>
</tr>
<tr>
<td>Third cutting - second year</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

Mean seed weights at 15 days following blooming varied considerably among clones, indicating possible differences in actual seed produced. It was of greater interest to obtain information concerning the amount of seed retained at 25 or 30 days after bloom. Entry 4 held considerably more seed than other entries at 30 days after blooming and continued to retain seed up to 40 days after flowering.

The amount of seed retained during maturation irrespective of the amount present in the head when shattering starts, may be of most use to the plant breeder. Relative seed retention at various periods beginning 15 days after bloom gives a measure of actual seed holding capacity. Percent seed retained at 15, 20, 25, 30, 35 and 40 days after bloom is illustrated in Figure 5 for the 12 clones. Entry 4 was
Table 22. Mean grams of seed per panicle of 12 reed canarygrass clones harvested at five-day intervals beginning at 15 days after bloom

<table>
<thead>
<tr>
<th>Entry no.</th>
<th>No. of heads (gms.)</th>
<th>Mean wt. of heads (gms.)</th>
<th>No. of heads (gms.)</th>
<th>Mean wt. of heads (gms.)</th>
<th>No. of heads (gms.)</th>
<th>Mean wt. of heads (gms.)</th>
<th>No. of heads (gms.)</th>
<th>Mean wt. of heads (gms.)</th>
<th>No. of heads (gms.)</th>
<th>Mean wt. of heads (gms.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>.516</td>
<td>33</td>
<td>.331</td>
<td>22</td>
<td>.113</td>
<td>17</td>
<td>.026</td>
<td>8</td>
<td>.022</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>.294</td>
<td>22</td>
<td>.092</td>
<td>23</td>
<td>.043</td>
<td>22</td>
<td>.030</td>
<td>13</td>
<td>.011</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>.213</td>
<td>21</td>
<td>.066</td>
<td>25</td>
<td>.022</td>
<td>13</td>
<td>.011</td>
<td>8</td>
<td>.024</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>.197</td>
<td>24</td>
<td>.102</td>
<td>22</td>
<td>.067</td>
<td>17</td>
<td>.019</td>
<td>5</td>
<td>.164</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>.225</td>
<td>13</td>
<td>.162</td>
<td>8</td>
<td>.130</td>
<td>4</td>
<td>.070</td>
<td>9</td>
<td>.007</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>.222</td>
<td>22</td>
<td>.115</td>
<td>15</td>
<td>.051</td>
<td>9</td>
<td>.007</td>
<td>7</td>
<td>.024</td>
</tr>
<tr>
<td>9</td>
<td>27</td>
<td>.587</td>
<td>29</td>
<td>.352</td>
<td>24</td>
<td>.208</td>
<td>15</td>
<td>.070</td>
<td>7</td>
<td>.024</td>
</tr>
<tr>
<td>10</td>
<td>14</td>
<td>.314</td>
<td>16</td>
<td>.121</td>
<td>14</td>
<td>.049</td>
<td>7</td>
<td>.023</td>
<td>5</td>
<td>.164</td>
</tr>
<tr>
<td>11</td>
<td>25</td>
<td>.431</td>
<td>35</td>
<td>.111</td>
<td>15</td>
<td>.035</td>
<td>12</td>
<td>.004</td>
<td>8</td>
<td>.070</td>
</tr>
</tbody>
</table>

Entry numbers correspond to accession sources and selection numbers as follows:

Entry number 1 2 3 4 5 6 7 8 9 10 11 12
Accession Ph-29 Ph-29 Ph-29 Ph-47 Ph-12 Ph-12 Ph-12 Ph-28 Ph-31 Ph-8 Ph-36 Ph-29
source
Selection 20-42 21-39 21-10 39-9 48-14 48-14 NB-16 19-34 36-7 41-14 36-7 20-7
number
superior, in relative seed holding ability while Entries 6
and 7 were intermediate. The remaining entries were poor in
relative seed retention. Entries 11 and 12, illustrated by
dashed lines in Figure 5, were selected as being susceptible
to seed shattering and appear representative of commercial
reed canarygrass in this respect.

Regression coefficients for seed retained on periods
after bloom were computed for the 12 clones and are presented
in Table 23. The regression value for Entry 4 ($b = -0.76$)
was considerably smaller than for other entries. An F test
for heterogeneity of regression coefficients was made using
a technique outlined by Kempthorne (42) and the results ap­
pear in Table 24. Although the mean square for differences
among slopes is larger than the deviations from individual
slopes, the F-value (1.22) is not significant at the 5 per­
cent level of probability. This may be partially due to the
large deviations from individual slopes and to the lack of
linearity of regressions.
Figure 5. Relative seed retention of 12 reed canarygrass clones harvested at five day intervals beginning 15 days after blooming (Amount of seed held 15 days after bloom considered to be 100 percent)
Table 23. Regression coefficients of percent seed retained on days after bloom, for 12 reed canarygrass clones

<table>
<thead>
<tr>
<th>Entry</th>
<th>Regression coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-6.54</td>
</tr>
<tr>
<td>2</td>
<td>-5.72</td>
</tr>
<tr>
<td>3</td>
<td>-6.12</td>
</tr>
<tr>
<td>4</td>
<td>-0.76</td>
</tr>
<tr>
<td>5</td>
<td>-5.76</td>
</tr>
<tr>
<td>6</td>
<td>-3.96</td>
</tr>
<tr>
<td>7</td>
<td>-4.42</td>
</tr>
<tr>
<td>8</td>
<td>-6.40</td>
</tr>
<tr>
<td>9</td>
<td>-5.78</td>
</tr>
<tr>
<td>10</td>
<td>-6.04</td>
</tr>
<tr>
<td>11</td>
<td>-6.30</td>
</tr>
<tr>
<td>12</td>
<td>-6.20</td>
</tr>
</tbody>
</table>

\(^a\)Only the average days of 15, 20, 25 and 30 days from blooming to harvest were used in these calculations.

Table 24. F test for heterogeneity of regression coefficients of percent seed retained on days after bloom for 12 reed canarygrass clones

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common slope</td>
<td>1</td>
<td>42,666.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference among slopes</td>
<td>11</td>
<td>3,693.5</td>
<td>335.8</td>
<td>1.22</td>
</tr>
<tr>
<td>Individual slopes</td>
<td>12</td>
<td>46,360.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deviations from individual</td>
<td>24</td>
<td>6,588.0</td>
<td>274.5</td>
<td></td>
</tr>
<tr>
<td>Total within clones</td>
<td>36</td>
<td>52,948.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

The amount of genetic change which may be effected within any species by selection is largely determined by the amount of variation present. Consequently, information concerning this variability for agronomically-important characteristics is of value to a plant breeder in choosing the most efficient breeding technique. The present investigation was initiated to provide information concerning variation for certain agronomic characteristics that subsequently would be of value for the improvement of reed canarygrass by breeding.

Plantings of seed from various sources indicated that material from areas of warmer winter climates was not sufficiently hardy to withstand winter conditions found in Iowa. Ph-59, an accession from Alabama, Ph-66, an accession from Arkansas, and S-1, a clone from the Superior strain developed in Oregon, all were very susceptible to winter injury and thus, appear of limited value as a source of future breeding material for the North Central Region. The introduction from Turkey, Ph-64, although high in percentage of leaves was susceptible to a leaf disease caused by Stagonospora foliicola. The other accessions, primarily from the North Central Region, generally appeared desirable for selection and breeding purposes.

Differences among seed accessions in forage yield in
solid stands were greater when reed canarygrass was grown alone than when grown with Ladino clover. This tends to substantiate the point that grass selections may be evaluated more effectively in plantings of grass alone rather than in grass-legume mixtures, especially if the components are not determined. Some reed canarygrass entries in solid stands of grass alone compared favorably with bromegrass and orchardgrass for annual yield and generally produced more aftermath growth. This is in general agreement with findings of other authors (22, 33, 37 and 78), both in the United States and other countries. In 1956 at Ames, rainfall was below normal and in 1957 it was near normal. The relatively large second and third cutting yields for the two years indicate that reed canarygrass produces a large amount of aftermath under both dry and normal moisture conditions compared to bromegrass and orchardgrass.

It was also noted from the forage yield tests of grass alone that many of the seed accessions produced as much or more total forage and aftermath than the Ioreed synthetics. This indicates it may be possible to maintain or improve these characteristics of the species compared with the commercial strain, Ioreed.

The ability of grasses to yield substantial quantities of high quality seed has become increasingly important with increased pasture seedings in the United States. Reed
canarygrass would have greater utilization if high seed yield and shattering resistance could be combined into one strain. In this investigation seed yield tests were grown at two locations for two years to study variation among 27 seed accessions for panicle production, seed yield and percentage germination. Seed yields and germination percentages were generally greater than those reported by other authors (4, 24, and 77). This may have been due in part to the harvest methods used. In this study paniced culms were cut and loosely bagged when approximately 50 percent of the seeds were brown, and subsequently allowed to dry in the greenhouse. Germination percentages, all 95 or above, compare closely with values found by Griffeth (24) when a beater-type harvester was used; however, he obtained very low yields (15 pounds per acre) by this method. Use of more common types of harvesters such as combines and headers, gives seed which often germinates very poorly. Griffeth (24) found in one study that commercial reed canarygrass seed germinated 79 and 74 percent when harvested with a header and combine, respectively.

Variation among seed lots for seed yield and panicle production were generally substantial. Many of the selections, especially Ph-2 and Ph-23 which were selected from plants with apparent resistance to seed shattering at maturity, yielded
more than the Ioreed synthetics. This is of interest, since Ioreed was produced by combining clones which appeared phenotypically superior in seed production. However, the plants making up this synthetic were not tested for combining ability for seed production. Panicle production was generally closely associated with seed yield in these studies. This is expected, although any differential in shattering among entries may affect such an association. The closer correlation of panicle production score rather than panicle count with seed yield indicates that the former more economical procedure may give a relatively satisfactory indication of seed yield. In addition to panicle production, a study of other components of seed yield such as seed holding capacity, fertility of florets and seed size should be included in future studies of seed production.

Seed yields for each location and year were not presented in the results of this study. However, compared to 1956, yields in 1957 were approximately eight times larger at Ames and two times larger at Cresco. Increased yields in 1957 may have been partially due to more favorable rainfall, improved stands, more panicles produced the second year after establishment or the inorganic fertilizer applied. This latter condition presents a production problem that is in need of study, i.e., rates and kinds of fertilizer necessary for optimum seed yields.
The space-planted nursery provided a more detailed study of variability in reed canarygrass. Alfalfa was seeded among the grass plants to offer more uniform competition, prevent excessive spreading, provide nitrogen and control weeds. The nursery was cut at a uniform height with a rotary field chopper following measurements made in June and again in August. This method of space-planted nursery maintenance appeared more satisfactory than clean cultivation among the grass plants.

The variation among seed accessions was large for all eight characteristics studied. The range among all plants within seed accessions was June 1 to June 16 for date of bloom, 18 to 47 percent for leafiness and 9 to 25 millimeters for leaf width. The mean leafiness calculated on a panicked culm basis for these reed canarygrass seed accessions was 27.8 percent, which is greater than the leafiness found for 161 desirable bromegrass selections (20.6 percent) studied by Grennell (23). On the basis of these data, it appears possible to increase leafiness which is already quite high in this species, since several accessions were more leafy than Ioreed.

Estimates of genotypic variation calculated by comparing mean plant-to-plant variances of seed accessions with clones were relatively high for leafiness percent (73 percent), leaf width (66 percent) and bloom date (48 percent), and considerably lower for hay vigor score (26 percent). Environmental
effects were more important in the case of hay vigor. Although no information concerning genotypic variation was found in the literature for reed canarygrass, estimates of genotypic variation for several characteristics in bromegrass were made by Lebsock and Kalton (49). They found a very similar value for leaf width (67 percent) and a higher value for hay vigor (60 percent). Values for leafiness, leaf width and bloom date found in this study compare closely with values found for bromegrass by Grennell (23) when variance components were used. The ten replications of accessions from open-pollinated seed and clones in the present study probably permitted reliable estimates of genotypic and environmental variation. Results indicate that genetic progress might be expected if selecting for leafiness, leaf width and bloom date in the nursery. Evaluation of hay vigor by observing spaced plants would probably be impractical since it appears low in heritability and also because the association between vigor of spaced plants and actual yields in solid stands is low.

A knowledge of intercharacter relationships among important forage characteristics has application in a breeding program. Since higher leafiness generally increases forage quality, the relationships of leafiness with other characteristics was of interest. They were estimated by the use of simple, phenotypic and genotypic correlations. These correlations, although not consistent, generally indicated a nega-
tive and low association between leafiness and leaf width, which is in agreement with findings for bromegrass by Grennell (23). There was apparently a positive genotypic correlation between leafiness and hay vigor, although a simple correlation of these characteristics was negative and low. Grennell (23) found an association between these two characters in bromegrass. No definite conclusions can be reached concerning the association of leafiness and bloom date, since an unrealistic genotypic correlation greater than unity was computed.

The significance of planting methods in relation to the most effective evaluation of breeding material is controversial. It appears from the results of this study that hay and aftermath vigor scores based on spaced plants fail to indicate forage yielding ability or recovery capacity in solid stands. Although critical information concerning the effectiveness of selection among spaced plants is necessary, these results suggest the need of progeny testing in solid stands for such characters of low heritability.

As emphasized in many sections of this dissertation, a better understanding of the genetic variation for seed shattering is needed in reed canarygrass. Although Hanson and Carnahan (28) have stated that variation in shattering in this species can be attributed to differences in maturity among selections rather than to inherent differences in
ability to hold seeds after maturity, the present study indicates that differences among clones exist independent of date of bloom. One clone out of the 10 selected as apparently resistant to seed shattering in the space-planted nursery was particularly outstanding in seed holding ability for a long period after blooming. Even though the frequency of genes controlling resistance to shattering of seed in reed canarygrass probably is low, it appears from these results that a definite possibility exists for increasing seed retention since there are inherent differences within the species for this characteristic. An insight into the ease or difficulty of changing this attribute by breeding can be obtained by future progeny tests of selected material. Accessions that appeared to possess the most shattering resistance were Ph-12 from south-central Minnesota and Ph-47 from northeastern Iowa.

A plan for future study of selected plants from the space-planted nursery with emphasis on seed shattering resistance is outlined here for future reference. Several hundred plants were selected from the nearly 6,000 spaced plants in the nursery in the fall of 1957. The basis of selection primarily was shattering resistance but desirable leafiness, disease resistance, and hay and aftermath vigor also were considered. These plants were moved into the greenhouse in late fall and will be vegetatively propagated so that four or five replications of single plants can be included in a top-
cross nursery next spring. Propagules of the selected clones also will be established in a separate maintenance nursery. Ioreed, the topcross parent, will be sown in rows alternating with the spaced clones to be tested. During the second growing season, the clones in the topcross nursery will be evaluated for such traits as seed shattering, open-pollination fertility, seed yield per panicle and plant, leafiness, leaf disease intensity, hay and aftermath vigor and bloom date on a replicated basis. Seed shattering could be evaluated by a method similar to the one used in this study. As a suggestion, six panicles per clone could be tagged as to date of bloom. Then some panicles could be harvested about 15 days later and the others 25 or 35 days after bloom to determine seed productivity and retention. Seed harvested from the remaining panicles of each clone should be sufficient for replicated topcross progeny tests. Three to five years would be necessary to properly evaluate progeny performance with respect to seed and forage characteristics. If feasible, an additional evaluation of palatability would be of value.

On the basis of topcross performance, elite clones of similar maturity could be selected and placed in isolated recombination blocks for production of Syn-1 seed. The synthetics would then be tested and if more improvement appeared
necessary, representative samples of Syn-1 or Syn-2 seed could be used to establish a space-planted nursery for initiation of a second cycle of selection. A recurrent selection program of this nature might provide information basic to the breeding of similar grasses and could result in an improved strain of reed canarygrass.

During the course of the present investigations, many factors concerning reed canarygrass production and breeding appeared in need of initial or further study. Some of these are noted as follows:

1. Components of seed-yield such as panicle production, fertility of florets and seed size together with their interrelationships.

2. Extent of genotypic variation for seed shattering resistance.

3. Combining ability differences for agronomically-important characteristics.

4. Chemical composition studies of the forage from material of divergent sources and origins to provide some basis for improvement of forage quality.

5. Palatability differences among variable material within the species by use of livestock. This research should be conducted in conjunction with chemical studies.

6. Organisms, such as *Stagonospora foliicola*, and their possible effects on forage quality and other agronomic traits.
7. Inheritance of important characteristics. In this regard, attempts to find easily identified, simply inherited characters in order to study the nature of pollination within crossing blocks and find required isolation distances necessary for crossing blocks would be worthwhile.

8. Feasability of producing commercial hybrids in this highly self-sterile species.

9. Legumes which grow well in association with this grass. This information would be of value to the breeder in evaluation of breeding materials.

10. Soil fertility needs for optimum seed and forage yields.

11. Performance of different synthetic generations with respect to seed and forage yield.

12. Management practices suitable for optimum production of high quality hay or pasture.

Some of these factors fall within the realm of crop breeding, while others are physiological or pathological in nature. Information obtained in such studies should be valuable in bringing about a greater utilization of reed canarygrass for forage purposes in the future.
SUMMARY AND CONCLUSIONS

1. The agronomic performance of 47 seed accessions and three clones of reed canarygrass, _Phalaris arundinacea_ L., was studied in replicated forage and seed yield tests, a space-planted nursery and a seed shattering experiment. Objectives were to measure differences among accessions for seed and forage productivity, to measure plant-to-plant variability for certain characteristics and estimate the extent of genotypic variability, to determine the interrelationships among certain characters, to compare performance of accessions in spaced and broadcast plantings and to study seed shattering.

2. Forage yields of 15 reed canarygrass seed accessions were compared with bromegrass and orchardgrass in stands of grass alone at one location for two years and in grass-Ladino clover mixtures at two locations for two years. Yield differences among entries were larger when grass was grown alone than when grown with Ladino clover and several reed canarygrass accessions yielded more annual forage and aftermath growth than bromegrass or orchardgrass. Ph-40, the highest yielding reed canarygrass entry, produced an average of 2.23 tons per acre annually in solid stands compared to 2.00 and 1.80 tons per acre for bromegrass and the mean of two orchardgrass strains, respectively. Average second cutting yields, as a measure of recovery growth were 0.68, 0.28 and 0.38 tons.
per acre for Ph-400, bromegrass and orchardgrass, respectively.

3. Seed yields and panicle production of 27 seed accessions were studied for two years at two locations. Mean yields averaged over years and locations ranged from 111 to 201 pounds per acre with accessions selected for apparent resistance to seed shattering generally yielding more than accessions from commercial seed lots. Panicle production scores in 1956 and panicle counts in 1957 both gave reliable predictions of relative seed yield as indicated by correlation coefficients.

4. In forage and seed yield tests three synthetic generations of Ioreed were compared as checks with other accessions. Although there was some variation among generations, several other accessions yielded more forage and all were higher in seed production. This indicates good possibilities for improvement of seed and forage traits of this species.

5. In the space-planted nursery consisting of ten replications of 39 seed accessions and three clones, highly significant differences were obtained among accessions for fall vigor and greenness, winter injury, aftermath vigor, hay vigor, bloom date and leafiness. Differences for leaf width were significant only at the five percent level. Ranges in leafiness, leaf width and bloom date on a single plant basis were from 18 to 47 percent, from 9 to 25 millimeters and from
June 1 to June 16, respectively. Two accessions of southern origin and a clone from Superior were severely winter injured. Many seed accessions appeared more desirable than Ioreed for the characteristics studied.

6. Mean plant-to-plant variance for the two clones was considerably less than for seed accessions for bloom date, leaf width and leafiness, and slightly less for hay vigor in the space-planted nursery. However, seed accessions did not differ significantly in plant-to-plant variances for any of these four characteristics, indicating a similarity in degree of variability. Estimates of genotypic variation were 73, 66, 48 and 26 percent for leafiness, leaf width, bloom date and hay vigor, respectively. Approximately 74 percent of the total variability for hay vigor was due to environmental effects. These high estimates of genotypic variation for leafiness, bloom date and leaf width indicate that genetic advance might be effected by phenotypic selection for such characteristics in spaced plantings.

7. Intercharacter associations were studied by calculating simple, phenotypic and genotypic correlation coefficients. It was concluded that leafiness was not associated to any degree with leaf width. High leafiness percentage appeared to be associated with hay vigor since the genotypic "r" value was 0.58.

8. Methods of planting were compared by use of correla-
tions between vigor scores in the space-planted nursery and yields in solid stands. The "r" values were low and not significant in all cases, indicating the difficulty of improving yield and recovery of reed canarygrass for solid plantings by selection among spaced plants.

9. Measurements of seed shattering among replicated propagules of 12 clones selected from the space-planted nursery indicated that inherent differences do exist within this species for shattering resistance. Individual panicles were harvested at three day intervals beginning 15 days after bloom and one selection was found to hold a quantity of seed up to 40 days, while selections similar to commercial reed canarygrass lost nearly all seeds by 25 days after blooming. This indicates that improvement should be possible for seed retention in this species.

10. Plans for future study of selected material from the space-planted nursery were presented together with a listing of factors in need of initial or added research.
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ACKNOWLEDGMENTS

The author expresses sincere appreciation to Dr. Robert R. Kalton for his generous advice and assistance throughout the conduct of the experiment, and for his many helpful suggestions during preparation of the manuscript. Thanks also are extended to Dr. C. P. Wilsie for constructive criticism of the manuscript. Appreciation is extended to the author's wife, Elsie, for her assistance and encouragement throughout the period of study.