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(Dr. Rod V. Frakes)

Visual identification of easily measured characteristics related to seed yield may aid the plant breeder in maintaining or improving seed yield in grasses. This study was undertaken to describe relationships between easily identified and measured morphological and seed yield characteristics of tall fescue (Festuca arundinacea, Schreb.) and determine their parent-progeny relationship.

Twenty selected parent genotypes, their open-pollinated (OP) and self-pollinated (S_1) progenies were space planted in a randomized block design experiment at Corvallis, Oregon. Data were collected on flag leaf area, dry weight of twenty flag leaves, specific flag leaf weight (SFLW), girth, stem diameter, panicle area, panicle length, panicle gross weight, panicle seed weight, fertility index and seed yield for 1978 and 1979.

For most of the characteristics measured significant differences were detected among the parents, among the OPs, as well as among the S_1s. In most cases, the S_1s showed a lower performance than their respective parents and OP progeny, while the OPs exceeded that of their parents. The parents exhibited larger mean squares than their progenies indicating more variability among the parents. The combined analysis of variance reveals that the parents and their progenies interacted significantly with years for all the characteristics except fertility index. Relatively high parent-progeny regression values were observed for the traits under study suggesting reasonable transmissibility from parent to progeny. All except SFLW, were significantly and positively associated with seed yield. The simple correlation, path coefficient and stepwise multiple regression analyses indicated the characteristics most closely related to yield were girth and panicle seed weight.

The results of this study suggest that tall fescue seed yield improvement would result from selection for increased girth and/or panicle seed weight. Under low plant competition, the easily measured characteristic, girth, appears as the most important selection criterion for increasing seed yield.

Interrelationships of Tall Fescue Seed Yield Characteristics in Selfed and Open-Pollinated Progeny and Their Parents

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Interrelationships of Tall Fescue Seed Yield Characteristics in Selfed and Open-Pollinated Progeny and Their Parents

Improved forage yield is regarded as the ultimate objective in many grass breeding programs. Even so, superior seed production potential of grass cultivars has been recognized as an important criterion for accepting a variety (Harlan, 1960). Low, positive and non-significant correlations between seed and forage yield have been reported in many forage grasses (Lawrence, 1962; Nielson and Kalton, 1959; Ross and Adams, 1955).

Seed yield in perennial grasses is a complex characteristic depending on tiller formation, the number of fertile tillers, florets, seed and seed weight. Breeders may be able to increase seed yield more easily and rapidly by selecting for less complex characteristics closely related to yield, than by selection directly for yield.

Genetic variability for seed yield, tiller number, panicle number, seed number, seed weight, fertility index and other seed characteristics has been reported in many forage grasses (Baenziger and Knowles, 1962; Christie and Kalton, 1960; Raeber and Kalton, 1956; Slinkard, 1965; Thomas, 1967). Seed characteristics of crested wheatgrass (Agropyron desertorum, Schult.) were found to be highly heritable (Baenziger and Knowles, 1962; Schaaf and Roger, 1963; Schaaf, 1976). Thomas (1967) examined a nine clone diallel in tall fescue (Festuca arundinacea, Schreb.) and reported narrow-sense heritability estimates of 0.57,

0.42, 0.62 and 0.37 for tiller number, seed number, seed weight and seed yield, respectively. His findings suggest that seed characteristics in tall fescue are under genetic control and their improvement through breeding is possible. Narrow-sense heritabilities in excess of 30% for seed yield, panicle number, fertility index, seed weight and bloom date of bromegrass (Bromus inermis, Leyess) are documented (Christie and Kalton, 1960; Nielson and Kalton, 1959).

Previous studies have established that seed yield characteristics in perennial forage grasses are closely associated (Deffinbaugh, 1978; Dewey and Lu, 1959; Trupp and Slinkard, 1965). Plant girth (circumference), panicle gross weight, panicle seed weight, panicle length, anthesis date and upper stem diameter were found to be highly correlated and accounted for a large portion of the variation in tall fescue seed yield (Deffinbaugh, 1978). Nielson and Kalton (1959) reported genotypic correlations of 0.75, 0.59 and 0.04 for bromegrass seed yield with panicle number, fertility index and seed weight, respectively. Fertility and plant size were identified as the most important components of crested wheatgrass seed yield but they were negatively correlated (Dewey and Lu, 1959).

Some reports suggest improving grass seed production by increasing the number of fertile tillers (Griffiths et al., 1974; Lewis, 1963). Others (Deffinbaugh, 1978; Raeber and Kalton, 1956; Schaaf, 1976) tried easily measured characteristics and identified seed components as fertile seed numbers or weights or ratios of cleaned to uncleaned seed weight (fertility index). The latter approach requires much less time and would allow the scientist to examine a larger number of plants.

This study was designed to obtain more information on: a) the identification of easily measured characteristics related to tall fescue seed yield, which may serve as selection criteria for the plant breeder, b) the interrelationships among these characteristics, c) the transmissibility of these characteristics from parent to progeny and d) an assessment of the genotype x year interaction for the characteristics measured.

MATERIALS AND METHODS

A progeny testing spaced-plant nursery consisting of 20 tall fescue genotypes, and their open- and self-pollinated progenies was established for this study. Tall fescue is a naturally cross-pollinated species with about 33% of the plants producing seeds on selfing. To be sure of having enough selfed seeds to establish this nursery, 100 morphologically different genotypes of different origin in an established plant introduction nursery were identified in the spring of 1977.

Self-pollinated seeds (S_1) were obtained by enclosing in a paper bag prior to anthesis, ten panicles of each parent clone. Prior to seed shattering, the rest of the panicles were enclosed in a bag to provide the open-pollinated seed (OP). Only 30 out of the 100 self-pollinated genotypes produced enough selfed seed to establish the required number of seedlings. Twenty genotypes were selected from these 30, based on diversity of origin. Seeds were planted in a sterile media, moistened and held at 2°C for a week to break dormancy. After germination the seedlings were individually transplanted in peat pots in the greenhouse. The parent clones were lifted from the introduction nursery, vegetatively increased and their propagules also established in peat pots.

On September 7, 1977, the seedlings and propagules were transplanted in the field on the Oregon Agricultural Experiment Station,

Corvallis. The experiment was arranged in a randomized block design with three replications, each consisting of the 20 parents, 20 OP progeny and 20 S_1 progeny. Each entry included 15 plants established on 91.44 cm centers. A total of 2700 plants were used in this nursery, excluding border plants.

Several characteristics associated with seed yield were measured in the spring and summer of 1978 and 1979 as follows:

Girth: During the first half of June, all of the plants in the nursery were snuggly tied 50 cm above the ground level and their circumference measured in centimeters at this height.

Prior to seed shattering, 30 stems with normal mature panicles were taken at random from each entry. They were enclosed in a paper bag, allowed to air dry in shade and used in the following measurements:

Stem diameter: This was represented by the average of 30 randomly chosen stem diameters per entry measured at the second internode below the panicle. These measurements were taken with a wire size gauge and converted to millimeters (mm).

Panicle length: The average length in centimeters of 30 panicles per entry was measured from the lowest primary pedicel to the tip of the panicle.

Panicle gross weight: Represented by the average dry weight in grams of the 30 unthreshed panicles for each entry. The panicles were left to dry in a shaded room for 15 days before measuring the panicle gross weight.

Panicle seed weight: Represented by the average weight in grams of 30 threshed panicles per entry.

Fertility index: Expressed as a ratio of panicle seed weight to panicle gross weight.

Yield: The plants in each entry were cut by hand, bulked in large paper bags and dried in a shaded room. They were threshed with a plot thresher, cleaned with a clipper cleaner and weighed in grams. The clean seed weight of the 30 panicles used for panicle seed weight was added to give the total seed weight per entry, then divided by the number of plants to provide seed yield per plant.

The following four additional traits for which information is lacking were measured to examine their relationships to seed yield.

Flag leaf area (cm^2): Twenty fully expanded flag leaves were taken at random from each entry. Their leaf area was determined by an electronic leaf area meter (Licor LI 3000)[1]. The flag leaves were oven dried at 70°C for 48 hours and weighed in grams to calculate the 20 flag leaves dry weight. Specific flag leaf weight (SFLW) was expressed as a ratio of 20 flag leaves dry weight (g) to 20 flag leaves area (square decimeters).

Panicle area: The area per panicle in centimeters squared was determined on 30 randomly selected mature panicles per entry, measured with the electronic leaf area meter.

Since the parents were selected to set selfed seed and were from diversified morphology and origin, with no realistic random mating reference population, a fixed effects statistical model was used to analyse the data. Each season's data are analysed separately using

[1]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product and does not imply its approval to the exclusion of other products that may also be suitable.

the analysis of variance procedures to test for differences among generations, and among entries within generations. The general error term was used for testing significance of the various progeny groups. The data were further analyzed as a split plot in time, with entries as the whole plot treatments, and years as the subplots to give the combined analysis for testing genotype x environment interactions. Parent-progeny relationships were studied by: a) the regression of S_1 progeny on parents and b) the regression of OP progeny on parents. The simple correlation coefficients among the 11 characteristics were determined in all possible combinations. The stepwise multiple regression analysis was used to identify the characteristics that were closely related to yield and to rank them according to their priority in accounting for the variation in yield. The correlations of girth, panicle length, panicle gross weight, panicle seed weight and fertility index with yield, were further analyzed by the path coefficient analysis as detailed by Dewey and Lu (1959). Correlations, stepwise regressions, multiple coefficients of determination (R^2) and path coefficients were all based on two year averages for all entries.

RESULTS AND DISCUSSION

For most of the characteristics measured in both seasons, the S_1s were less vigorous than their corresponding parents and OPs while the OPs exceeded their parents. The relative variability among the parents and progenies (OP and S_1) for each characteristic and in each year is shown by the analysis of variance mean squares (Table 1). The parents differed significantly for all characteristics except SFLW and fertility index in 1978. OP mean squares were significant for all characteristics with the exception of 1978 SFLW. The characteristics displayed highly significant variation among the S_1s except for SFLW in 1979. This significant variation for all the characteristics indicates the presence of genetic diversity among the parents. In general, the parents were considerably more variable than their corresponding OPs (Table 1). The S_1 mean squares were larger than those of OP which is in agreement with the findings in bromegrass and tall fescue (McDonald et al., 1952; Ross and Adams, 1955; Thomas, 1967).

Genotype-environment interactions

In the combined analysis of variance, the interactions of years with entries, parents, OPs and S_1s were significant for flag leaf area, panicle area, panicle gross weight and panicle seed weight (Table 2). For the dry weight of flag leaves, SFLW, girth and panicle length, year x entries, year x parents and year x S_1 interactions were significant.

Only year x entries and year x OP interaction effects were significant for stem diameter. Year x entries and year x S_1 mean squares were significant for yield. The interaction of years with genotypes and progenies for fertility index were small and not significant. These results suggest that fertility is fairly stable over years and not greatly affected by variation in the environment confirming similar findings in intermediate wheatgrass (Agropyron intermedium, Beauv.) (Slinkard, 1965). Parents and S_1s seem to be more affected by the variation in the environment than the OPs. The open-pollinated seedlings are expected to be more vigorous and have higher yield during the first season than the S_1s because of their larger seeds and consequently greater seedling vigor. This is quite advantageous in a space-planted nursery and may lead to stability over years. The establishment of the parents from cuttings and the progenies from seedlings may also have bearings on these seasonal interactions. The significant interactions with years shown by most of the characteristics reflect their instability over years and emphasizes the importance of more than one year testing.

Parent-progeny relationship

In this study, parent-progeny relationships were used as a measure of transmissibility for each characteristic rather than an estimate of heritability. Since the parents were selected for selfed-seed set and from diversified origins and morphology, the genetic assumptions of random selection was not met. The parents were selected from an

introduction nursery which cannot be designated as a realistic reference population to which the heritability estimates will apply.

The regression coefficients (b) as well as the coefficients of determination (r^2) for flag leaf area, dry weight of flag leaves, stem diameter, panicle length, panicle area, panicle gross weight and panicle seed weight were relatively high, significant and consistent within years and over the two years (Table 3). The b values and the corresponding r^2 values of these characteristics were higher for the S_1s than OPs. With either, however, the relatively high b value suggests that parental performance can be used to predict progeny performance for these characteristics. The b and r^2 values in year one and year two for fertility index and SFLW were inconsistent. The regression values for fertility index in this study are similar to those previously reported in other grasses (Raeber and Kalton, 1956; Slinkard, 1965; Trupp and Slinkard, 1965).

Girth and yield showed relatively low, non-significant S_1 regressions and r^2 values. Their OP regressions and r^2 were relatively high and significant, particularly in 1979 and over the two years. Low and high heritabilities for grass seed yield have been reported (Nielson and Kalton, 1959; Schaaf, 1976; Schaaf and Roger, 1963; Thomas, 1967), but generally yield heritability estimates are low.

ASSOCIATIONS AMONG CHARACTERISTICS

Simple correlation analysis

The simple correlation coefficients between all characteristics using entry means over years are listed in Table 4. They reveal that tiller size characteristics, i.e., flag leaf area, weight of flag leaves, stem diameter, panicle length, panicle area, panicle gross weight and panicle seed weight were significantly and highly associated. With the exception of panicle gross weight and panicle seed weight, their correlations with yield although significant were not so high. Flag leaf area, by itself, is not a good index of plant performance in cereals (McNeal and Berg, 1977), although it forms a major source from which photosynthates are translocated directly to the seeds. The data suggest that individual tillers with large flag leaves, thick stems, long, large and heavy panicles show high seed yield per tiller and not per plant. Yield per plant was significantly and highly associated with girth, panicle area, panicle gross weight, panicle seed weight and fertility index. Girth, which is a measure of the circumference of the plant, is determined by the number of tillers, size and number of leaves and the thickness of the stems. Since the objective of this study was the identification of easily measured characteristics associated with yield, girth was used to estimate the number of tillers and thus replace the tedious job of counting. Deffinbaugh (1978) suggested girth as a reasonable estimator of tiller number (r^2 = 46.4%) and also as one of the most useful single estimators of the variation in tall fescue spaced-plant seed

yield, and is in full agreement with the results of this study. A correlation coefficient of 0.44 between crested wheatgrass seed yield and plant size was reported (Dewey and Lu, 1959). Fertility index as used in this study measures the efficiency of seed production per panicle in the form of a ratio of weights, and hence, its high correlation with yield per plant may be questioned. SFLW was poorly and in some cases negatively correlated with yield and the other characteristics. The general trend in the forage studies also was that leaf area and SLW were not the major determinants of and in many cases poorly associated with forage yield (Song and Walton, 1975).

Stepwise multiple regression analysis

A stepwise multiple regression analysis was generated using seed yield as a dependent variable and the other characteristics as independent variables (Table 5). The independent variables were introduced into the stepwise regression equations according to the degree or magnitude of their association with yield. This is equivalent to ranking them according to their importance in explaining the variation in yield.

The multiple coefficients of determination (R^2) reveal that 86, 91 and 84% of the variation in the yield of 1978, 1979 and the means over the two years, respectively, was accounted for by the ten characteristics under study. The ranking of the variables was inconsistent between years but in each case the order in which the variables were introduced into the equation becomes somewhat meaningless after the third variable. Panicle seed weight was introduced first

in both 1978 and over the two years; and as the third in 1979. Girth was first in 1979 and second in 1978 and over the two years. Flag leaf area and panicle area were introduced late in most cases, an indication of their minor role in explaining the variation in yield. The stepwise multiple regression analysis emphasized the importance of girth and panicle seed weight in determining yield, a fact strongly confirmed by the high significant correlations among the three traits.

Path-coefficient analysis

Further insight into the interrelationships among the characteristics was obtained by the path-coefficients analysis. The results of the correlation and stepwise multiple regression analyses, and the biological cause and effect relationships were used to identify the variables for the pathway analysis: girth, panicle length, panicle gross weight, panicle seed weight, fertility index with yield as the dependent variable (Table 6).

Girth and panicle seed weight exerted the largest direct effects on seed yield. Their correlations with yield, although slightly reduced by the indirect, negative effects through panicle length and panicle gross weight, were still large, positive and highly significant. The direct effects of panicle length and panicle gross weight were negative and quite small. This helps explain their low ranking by the stepwise multiple regression analysis. Fertility index exerted a strong influence indirectly and positively through panicle seed weight and girth, but its direct effect, although positive, was low. In this study, fertility index is related to seed yield per plant

indirectly through panicle seed weight (Table 6). The indirect effect of fertility index on yield through panicle seed weight (0.49) was twice that via girth (0.24).

The path-coefficient analysis indentified girth and panicle seed weight as the two most important characteristics related to yield which agrees with the conclusion from the correlation and stepwise regression analyses. It disagreed with these analyses in identifying panicle length and panicle gross weight as unimportant seed yield characteristics.

SUMMARY

These data suggest that yield improvement would result from selection for increased girth and/or panicle seed weight. The two characteristics were reasonably transmissible from parent to progeny, had the highest correlations with yield and accounted for 81% of the variation in the yield of 1978 and over the two years. However, the simultaneous use of both characteristics as selection criteria for high yield per plant may not be effective because panicle seed weight is a tiller size characteristic while girth is a plant size characteristic. There have been suggestions of using panicle seed weight as a selection criteria for tall fescue seed yield (Deffinbaugh, 1978), but the correlations of 1979 data in this study showed that panicle seed weight was negatively correlated with girth ($r = 0.21$) as well as yield ($r = 0.21$). Panicle seed weight is a time consuming characteristic to measure, and, therefore, limits the number of plants that can be examined. Such difficulty may be overcome by selecting indirectly for panicle seed weight through panicle gross weight because they were highly associated ($r = 0.96$).

The second season data were given special consideration in this study because the plants were much larger and seed yields were much greater. They revealed interesting associations between panicle length and girth ($r = 0.96$); and panicle length and yield ($r = 0.90$). The direct effect of panicle length (0.11) on 1979 yield was small

while the indirect effect through girth (0.93) was very large. Based on these associations and the fact that both girth and panicle length were easily measured and highly transmissible from parents to progeny, it seems that rapid response to selection for high seed yield per plant in tall fescue could be accomplished by selecting long panicles within plants with high girth measurements.

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Table 1. Mean squares, error terms and coefficients of variation (C.V.,%) for eleven seed characteristics in tall fescue.

Characteristics	Mean Squares+									
	Parents		O.P.		S_1		Error		C.V.	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Flag Leaf Area	32.45**	31.51**	19.38**	5.11**	21.38**	16.50**	2.86	2.06	19.25	18.40
Dry Weight of 20 Flag Leaves	0.89**	0.73**	0.29**	0.21*	0.56**	0.43**	0.07	0.12	17.94	21.44
Specific Flag Leaf Weight	0.04	0.25**	0.03	0.12*	0.11**	0.01	0.03	0.07	20.87	23.78
Girth	15.10**	139.66**	6.68*	93.32*	5.86*	97.48**	3.44	45.57	16.17	16.43
Stem Diameter	0.30**	0.34**	0.17**	0.15**	0.23**	0.28**	0.04	0.04	7.46	7.54
Panicle Length	74.64**	57.06**	34.03**	27.67**	45.51**	35.66**	3.23	2.38	6.72	5.73
Panicle Area	78.45**	53.42**	29.88**	16.02**	45.61**	30.43**	14.26	2.83	17.41	8.75
Panicle Gross Weight	0.35**	0.17**	0.17**	0.06**	0.22**	0.08**	0.03	0.02	14.19	15.55
Panicle Seed Weight	0.30**	0.09**	0.18**	0.05**	0.17**	0.05**	0.02	0.01	20.10	21.03
Fertility Index	0.02	0.02**	0.05**	0.01**	0.06**	0.04**	0.01	0.01	17.92	10.24
Yield	623.14**	2646.00**	266.29**	1965.04*	106.98**	2315.13**	42.06	1003.28	26.04	34.47

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

+ Degrees of freedom = 19 for parents, O.P. and S_1.

Table 2. Interaction mean squares[+] for year x entries, parents, OP and S_1 for eleven seed characteristics in tall fescue for the years 1978 and 1979.

Characteristics	Year x			
	Entries	Parents	OP	S_1
Flag Leaf Area	13.07**	19.27**	9.47**	6.76**
Dry Weight of 20 Flag Leaves	0.25**	0.48**	0.10	0.19**
Specific Flag Leaf Weight	0.09*	0.14**	0.07	0.06*
Girth	87.33**	55.10*	39.39	36.17*
Stem Diameter	0.07**	0.09	0.07*	0.07
Panicle Length	9.58**	15.36**	3.63	8.90**
Panicle Area	17.73**	25.24*	12.93**	16.00*
Panicle Gross Weight	0.06**	0.09**	0.05*	0.05*
Panicle Seed Weight	0.05**	0.05**	0.05**	0.04*
Fertility Index	0.01	0.01	0.01	0.01
Yield	13.09**	7.95	8.00	8.99*

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

+ Degrees of freedom - genotypes, 59; parents, OP and S_1, 19.

Table 3. Parent-progeny regression coefficients (b), the standard errors (S. E.) of b and coefficients of determination (r^2) for eleven seed characteristics in tall fescue, n = 20.

Characteristics	O.P.								
	1978			1979			Means		
	b	S.E.	r^2	b	S.E.	r^2	b	S.E.	r^2
Flag Leaf Area	0.50**	0.14	0.42	0.30**	0.06	0.60	0.41**	0.10	0.47
Dry Weight of 20 Flag Leaves	0.29*	0.12	0.25	0.34**	0.09	0.42	0.32*	0.11	0.31
Specific Flag Leaf Weight	0.01	0.22	0.00	0.22	0.16	0.10	0.10	0.18	0.02
Girth	0.28	0.14	0.18	0.46**	0.15	0.33	0.44**	0.15	0.34
Stem Diameter	0.45**	0.14	0.35	0.57**	0.08	0.73	0.54**	0.10	0.64
Panicle Length	0.59**	0.08	0.77	0.64**	0.07	0.84	0.54**	0.08	0.74
Panicle Area	0.36**	0.12	0.34	0.47**	0.06	0.77	0.42**	0.08	0.58
Panicle Gross Weight	0.47**	0.12	0.45	0.42**	0.10	0.49	0.48**	0.10	0.54
Panicle Seed Weight	0.48**	0.14	0.39	0.46**	0.13	0.41	0.48**	0.13	0.43
Fertility Index	0.01	0.34	0.00	0.54**	0.16	0.39	0.36	0.29	0.08
Yield	0.28	0.14	0.18	0.39*	0.18	0.21	0.40**	0.11	0.41

Table 3. (Continued) Parent-progeny regression coefficients (b), the standard errors (S.E.) of b and coefficients of determination (r^2) for eleven seed characteristics in tall fescue, n = 20.

	S_1								
	1978			1979			Means		
Characteristics	b	S.E.	r^2	b	S.E.	r^2	b	S.E.	r^2
Flag Leaf Area	0.63**	0.12	0.61	0.65**	0.08	0.80	0.73**	0.10	0.76
Dry Weight of 20 Flag Leaves	0.63**	0.11	0.64	0.63**	0.10	0.69	0.69**	0.10	0.71
Specific Flag Leaf Weight	0.25	0.39	0.02	0.54**	0.09	0.67	0.76**	0.17	0.52
Girth	0.19	0.14	0.09	0.35	0.17	0.18	0.31	0.18	0.15
Stem Diameter	0.68**	0.13	0.62	0.69**	0.14	0.58	0.73**	0.12	0.69
Panicle Length	0.71**	0.08	0.82	0.71**	0.08	0.83	0.58**	0.09	0.68
Panicle Area	0.42*	0.15	0.31	0.46**	0.08	0.65	0.53**	0.12	0.52
Panicle Gross Weight	0.54**	0.13	0.47	0.50**	0.11	0.52	0.55**	0.12	0.54
Panicle Seed Weight	0.58**	0.16	0.59	0.54**	0.13	0.50	0.58**	0.11	0.58
Fertility Index	0.70	0.34	0.19	1.10**	0.28	0.47	1.08**	0.34	0.36
Yield	0.21	0.08	0.25	0.12	0.18	0.02	0.34	0.17	0.17

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 4. [+]Simple correlation coefficients between eleven seed characteristics over years in tall fescue[1].

Characteristics	1	2	3	4	5	6	7	8	9	10
1. Flag Leaf Area										
2. Dry Weight of 20 Flag Leaves	0.85									
3. Specific Flag Leaf Weight	-0.40	0.07								
4. Girth	0.15	0.17	0.14							
5. Stem Diameter	0.60	0.66	0.05	0.25						
6. Panicle Length	0.55	0.65	0.05	0.33	0.77					
7. Panicle Area	0.59	0.59	-0.09	0.46	0.77	0.72				
8. Panicle Gross Weight	0.64	0.57	-0.13	0.55	0.75	0.66	0.84			
9. Panicle Seed Weight	0.58	0.52	-0.10	0.55	0.66	0.57	0.78	0.96		
10. Fertility Index	0.35	0.27	-0.06	0.48	0.30	0.31	0.45	0.67	0.80	
11. Yield	0.37	0.36	0.02	0.78	0.37	0.39	0.60	0.75	0.80	0.72

+ Correlation coefficients calculated from means of 60 treatments (n = 60) over two years.

[1] The 0.05 and 0.01 significance levels (n = 60) are 0.25 and 0.32, respectively.

Table 5. +Multiple coefficients of determination obtained when seed yield per plant is used as a dependent variable in a stepwise multiple regression analysis and the order in which independent variables were introduced into the equation (1 - 10).

Characteristics	1978		1979		Means	
	Order	R^2	Order	R^2	Order	R^2
Panicle Seed Weight	1	.7000	3	.8938	1	.6347
Girth	2	.8143	1	.8869	2	.8056
Fertility Index	5	.8591	4	.9037	5	.8307
Stem Diameter	3	.8346	8	.9095	3	.8237
Dry Weight of 20 Flag Leaves	4	.8535	6	.9076	4	.8296
Panicle Gross Weight	9	.8643	2	.8884	9	.8349
Panicle Length	8	.8642	7	.9089	7	.8335
Specific Flag Leaf Weight	7	.8632	5	.9052	10	.8349
Flag Leaf Area	6	.8616	9	.9095	8	.8349
Panicle Area	10	.8643	10	.9095	6	.8317

+ Multiple coefficients of determination calculated from means of 60 treatments (n = 60).

Table 6. Correlations and path coefficients showing direct[+] and indirect effect of several characteristics on seed yield per plant using treatment means (n = 60) over two years.

Characteristics	Effects Via[+] (1) Girth	(2) Panicle Length	(3) Panicle Gross Weight	(4) Panicle Seed Weight	(5) Fertility Index	Correlation With Yield
(1)	<u>0.49</u>	-0.02	-0.07	0.33	0.04	0.78**
(2)	0.16	<u>-0.07</u>	-0.07	0.35	0.03	0.39**
(3)	0.27	-0.05	<u>-0.12</u>	0.58	0.06	0.75**
(4)	0.27	-0.04	-0.12	<u>0.61</u>	0.07	0.80**
(5)	0.24	-0.02	-0.08	0.49	<u>0.09</u>	0.72**

** Significant at the 1% level.

* Direct associations are underlined.

APPENDIX

Appendix Table 1. Identification and origin of the 20 tall fescue parent clones.

Entry	P.I.	Origin
1	264-361	Netherlands
2	235-125	Netherlands
3	257-742	Sweden
4	316-244	Sweden
5	203-728	Uruguay
6	287-820	Spain
7	283-277	Portugal
8	283-287	Czeckoslovakia
9	234-717	France
10	283-301	Tunisia
11	Syn 1002	OSU
12	265-363	Netherlands
13	283-289	Germany
14	TFM gen 19	OSU
15	Ky 37G1-307	Mo
16	Arnode	Mo
17	Syn D	North America
18	283-292	Wales
19	186-318	Denmark
20	297-909	Australia

Appendix Table 2. Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Flag Leaf Area (cm^2)		Dry Wt. of 20 Flag Leaves (g)		SFLW (g/dm^2)	
	1978	1979	1978	1979	1978	1979
			Parents			
1	7.50	9.83	1.32	1.39	0.87	0.71
2	12.04	9.42	1.98	1.92	0.85	1.05
3	5.64	9.28	1.40	2.60	0.86	1.40
4	7.09	5.26	1.67	1.34	0.91	1.26
5	8.21	9.28	1.67	2.08	0.99	1.37
6	9.12	16.01	1.59	2.59	0.89	.82
7	3.52	6.93	.53	1.15	0.75	.83
8	10.05	13.30	1.88	2.13	0.94	.81
9	12.32	9.06	2.31	2.44	0.95	1.36
10	9.21	5.51	1.67	1.69	0.92	1.54
11	9.32	7.62	1.43	1.47	0.67	.97
12	15.00	11.17	1.93	1.94	0.64	.87
13	8.45	6.29	1.04	1.79	0.62	1.47
14	4.60	4.55	1.10	1.35	0.86	1.49
15	5.62	11.75	1.04	1.54	0.91	.66
16	7.35	4.95	1.33	.98	0.91	.99
17	16.09	9.73	3.07	1.57	0.96	.87
18	7.43	5.41	1.52	1.32	1.02	1.25
19	8.50	5.04	1.36	1.38	0.82	1.35
20	4.93	3.90	.97	.98	0.91	1.25
Average	8.60	8.21	1.54	1.68	0.86	1.11

Appendix Table 2. (Continued) Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Number	Flag Leaf Area (cm^2)		Dry Wt. of 20 Flag Leaves (g)		SFLW (g/dm^2)	
	1978	1979	1978	1979	1978	1979
			OP			
21	10.50	8.82	1.57	1.50	0.80	0.85
22	13.73	9.13	1.99	2.02	0.70	1.12
23	11.99	9.32	1.95	2.20	0.81	1.14
24	8.04	7.31	1.32	1.69	0.85	1.16
25	12.04	9.38	1.81	1.81	0.75	.97
26	7.20	10.38	1.41	1.81	0.96	.87
27	8.49	6.19	1.40	1.56	0.83	1.65
28	11.44	8.73	1.47	1.81	0.79	1.05
29	16.12	8.75	2.09	1.94	0.65	1.10
30	9.43	7.31	1.53	1.59	0.85	1.12
31	11.07	7.77	1.55	1.45	0.07	.94
32	11.64	9.91	1.92	1.71	0.84	.88
33	9.71	9.02	1.27	2.06	0.67	1.15
34	6.35	6.73	1.17	1.44	0.95	1.07
35	7.90	7.94	1.36	1.39	0.87	.86
36	7.64	6.41	1.55	1.54	1.01	1.23
37	13.72	6.41	1.83	1.44	0.69	.87
38	9.24	7.63	1.24	1.38	0.67	1.13
39	13.06	7.67	2.23	2.10	0.85	1.35
40	10.06	5.96	1.36	1.43	0.68	1.22
Average	10.47	8.04	1.60	1.69	0.80	1.09

Appendix Table 2. (Continued) Means, standard errors of the mean ($s_{\bar{x}}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Flag Leaf Area (cm^2)		Dry Wt. of 20 Flag Leaves (g)		SFLW (g/dm^2)	
	1978	1979	1978	1979	1978	1979
			S_1			
41	7.62	7.50	1.12	1.11	.74	.74
42	8.54	6.96	1.85	1.50	1.23	1.14
43	5.51	7.52	1.31	1.73	1.17	1.13
44	6.37	4.39	.84	.98	.66	1.15
45	7.69	9.84	1.41	1.81	.92	.95
46	6.04	10.13	.91	1.93	.76	.96
47	4.43	5.54	.53	1.10	.59	.92
48	13.37	11.96	2.12	2.15	.79	.90
49	11.94	9.63	1.79	1.80	.75	1.11
50	7.47	6.29	1.35	1.54	.75	1.24
51	7.47	6.87	.84	1.25	.59	.91
52	9.45	10.80	1.37	2.04	.74	.95
53	4.29	6.42	.91	1.35	.86	1.20
54	4.01	4.74	.94	1.27	1.18	1.37
55	5.59	8.78	.73	1.48	.66	.80
56	4.74	3.60	.94	.90	.66	1.26
57	12.07	8.37	1.93	.49	.80	.91
58	6.24	5.22	1.13	1.08	.91	1.04
59	7.15	5.16	1.31	1.46	.95	1.42
60	5.46	4.38	1.01	1.03	.93	1.22
Average	7.27	7.16	1.22	1.45	.83	1.07
Grand Mean	8.78	7.80	1.45	1.61	0.83	1.09
CV (%)	19.25	18.40	17.94	21.44	20.87	23.78
$S_{\bar{x}}$	0.98	0.83	0.15	0.20	0.10	0.15
LSD (.05)	2.73	2.32	0.42	0.56	0.28	0.42
(.01)	3.61	3.07	0.56	0.74	0.37	0.55
(.001)	4.66	3.95	0.72	0.95	0.48	0.71

Appendix Table 2. (Continued) Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Girth (cm)		Stem Diameter (mm)		Panicle Length (cm)	
	1978	1979	1978	1979	1978	1979
			Parents			
1	8.17	45.38	2.41	2.63	22.11	23.71
2	9.90	46.02	3.13	3.41	27.91	33.69
3	6.80	26.88	2.39	3.13	28.96	33.39
4	10.83	37.64	2.39	2.73	24.75	23.72
5	11.67	48.13	2.91	2.93	29.58	28.19
6	12.80	38.28	2.69	2.74	27.24	32.20
7	11.60	46.42	1.90	2.47	20.54	24.06
8	14.25	53.50	2.90	2.85	36.14	32.18
9	13.87	48.82	2.90	3.24	37.90	34.97
10	12.70	53.28	2.69	2.74	24.15	24.78
11	14.97	41.96	2.81	2.70	30.65	27.80
12	13.73	37.01	2.51	3.08	24.62	28.62
13	14.03	51.74	3.02	3.17	35.45	34.09
14	11.90	47.82	2.69	3.00	24.31	28.43
15	11.90	53.37	3.02	3.36	27.70	31.87
16	12.90	53.11	2.27	2.34	21.12	22.72
17	10.87	41.47	2.90	3.12	27.59	28.75
18	15.10	49.29	2.90	2.83	29.74	25.63
19	10.17	45.51	2.59	2.79	24.28	27.72
20	9.27	44.46	2.27	2.08	21.16	19.70
Average	11.87	45.50	2.67	2.87	27.29	28.31

Appendix Table 2. (Continued) Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Girth (cm)		Stem Diameter (mm)		Panicle Length (cm)	
	1978	1979	1978	1979	1978	1979
			OP			
21	11.97	42.71	2.27	2.78	24.49	24.58
22	10.77	43.85	2.91	3.23	30.40	30.69
23	12.43	39.54	2.90	3.08	32.36	30.93
24	11.67	43.97	2.48	2.70	24.24	24.94
25	14.40	53.61	2.80	2.81	30.08	29.60
26	11.73	43.64	2.48	2.67	29.20	30.91
27	15.43	45.85	2.23	2.60	22.64	25.05
28	15.43	53.82	3.02	2.94	35.04	31.83
29	15.60	44.98	3.02	3.31	35.04	34.82
30	13.93	46.04	2.80	2.66	27.38	25.16
31	15.03	52.58	2.59	7.70	28.86	27.03
32	11.73	33.51	2.90	2.87	28.16	26.69
33	12.10	54.09	2.59	2.89	30.68	30.28
34	13.87	45.75	2.80	2.74	26.33	26.43
35	13.00	48.43	2.69	3.02	26.88	28.72
36	11.93	46.56	2.38	2.62	25.48	25.65
37	12.80	38.58	2.48	3.05	28.37	29.29
38	14.23	47.72	2.80	2.78	26.59	28.13
39	11.93	51.45	2.59	3.02	27.01	28.42
40	13.83	53.08	2.48	2.41	24.89	22.44
Average	13.19	46.49	2.66	2.84	28.21	28.08

Appendix Table 2. (Continued) Means, standard error of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Girth (cm)		Stem Diameter (mm)		Panicle Length (cm)	
	1978	1979	1978	1979	1978	1979
			S_1			
41	7.77	28.76	2.27	2.38	21.54	21.93
42	7.77	27.48	2.90	2.95	25.67	29.16
43	8.33	24.40	2.59	3.16	28.42	28.97
44	8.27	29.76	2.27	2.52	22.38	21.89
45	9.27	32.53	2.80	2.79	27.35	26.33
46	7.60	19.65	2.38	2.39	25.08	26.67
47	8.50	27.97	1.83	1.99	18.78	19.78
48	10.17	33.55	2.69	2.60	32.60	26.69
49	9.57	31.28	2.80	2.70	31.12	27.18
50	9.57	26.89	2.48	2.62	19.76	19.46
51	10.43	30.98	2.69	2.92	26.59	25.12
52	9.13	26.36	2.80	2.73	25.69	23.52
53	9.10	33.98	2.49	2.59	28.63	27.06
54	11.30	40.43	2.49	2.73	24.46	24.38
55	8.00	30.43	2.49	2.90	22.63	26.67
56	7.80	34.15	2.14	2.34	18.47	19.54
57	10.27	29.17	2.59	3.16	25.28	27.70
58	12.20	34.76	2.69	2.47	25.63	22.90
59	11.70	38.01	2.70	2.58	24.89	25.35
60	10.60	45.01	2.14	2.14	19.87	17.25
Average	9.37	31.28	2.51	2.63	24.74	24.38
Grand Mean	11.31	41.09	2.61	2.78	26.75	26.92
CV (%)	16.17	16.43	7.46	7.54	6.72	5.73
$s\bar{x}$	1.07	3.90	0.11	0.12	1.04	0.89
LSD (.05)	3.00	10.91	0.32	0.34	2.91	2.49
(.01)	3.97	14.42	0.42	0.45	3.84	3.29
(.001)	5.11	18.59	0.54	0.58	4.95	4.25

Appendix Table 2. (Continued) Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Panicle Area (cm^2)		Panicle Gross Weight (g)		Panicle Seed Weight (g)	
	1978	1979	1978	1979	1978	1979
			Parents			
1	19.32	17.39	1.11	.92	.85	.60
2	21.69	23.44	1.40	1.29	1.08	.80
3	17.75	25.13	.61	.77	.30	.39
4	20.93	15.59	1.05	.69	.85	.51
5	20.88	18.16	1.53	1.00	1.32	.77
6	22.42	23.68	1.32	1.07	1.09	.78
7	13.68	16.50	.67	.63	.52	.41
8	25.44	21.42	1.63	1.04	1.29	.79
9	30.68	22.27	1.51	1.13	.98	.79
10	20.82	16.99	.95	.82	.68	.49
11	28.42	22.07	1.34	.97	.81	.69
12	26.89	22.31	1.65	1.00	1.32	.60
13	30.83	28.61	1.78	1.35	1.33	.91
14	26.52	20.30	1.20	1.77	.99	.79
15	24.60	26.35	1.17	1.22	.89	.70
16	15.47	13.90	1.20	.53	.42	.31
17	29.10	23.20	1.43	1.03	.99	.71
18	29.32	22.08	1.59	1.03	1.19	.76
19	18.56	19.17	.78	.72	.53	.45
20	19.21	12.39	.82	.54	.64	.39
Average	23.13	20.55	1.24	.94	.90	.63

Appendix Table 2. (Continued) Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Panicle Area (cm^2)		Panicle Gross Weight (g)		Panicle Seed Weight (g)	
	1978	1979	1978	1979	1978	1979
			OP			
21	26.29	18.81	1.24	.86	.91	.60
22	26.00	21.69	1.39	.97	1.07	.58
23	24.19	24.46	1.08	.78	.61	.40
24	20.14	17.65	1.03	.76	.75	.53
25	27.54	21.27	1.63	.89	1.16	.60
26	21.45	20.24	.91	.80	.32	.45
27	17.75	18.68	.85	.72	.59	.49
28	23.67	20.00	1.54	1.01	1.07	.69
29	26.35	22.10	1.51	1.19	1.13	.82
30	23.53	18.93	1.23	.80	.82	.50
31	25.91	20.61	1.25	.76	.93	.49
32	22.41	21.26	1.55	.82	1.22	.59
33	27.33	23.95	1.33	1.09	.92	.79
34	18.95	21.20	1.27	.77	.74	.48
35	23.00	22.40	1.05	.89	.69	.53
36	17.80	17.07	.80	.65	.40	.35
37	26.10	22.65	1.42	1.06	.96	.74
38	26.42	18.16	1.40	.97	1.01	.72
39	20.74	21.35	1.12	.94	.74	.63
40	21.49	15.49	1.18	.68	.88	.47
Average	23.35	20.40	1.24	.87	.85	.57

Appendix Table 2. (Continued) Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Panicle Area (cm^2)		Panicle Gross Weight (g)		Panicle Seed Weight (g)	
	1978	1979	1978	1979	1978	1979
			S_1			
41	16.84	21.93	1.06	.53	.43	.34
42	17.42	29.16	.99	.81	.71	.49
43	18.51	28.97	.61	.57	.23	.24
44	14.85	21.89	.80	.59	.56	.40
45	24.40	26.33	1.42	.93	1.09	.63
46	16.58	26.67	.80	.60	.49	.34
47	10.22	19.78	.40	.41	.26	.24
48	24.41	26.69	.94	.64	.58	.40
49	19.52	27.18	1.17	.64	.55	.38
50	14.26	19.46	.57	.42	.22	.28
51	22.47	25.12	.94	.63	.62	.32
52	21.58	23.52	1.24	.68	.93	.37
53	24.76	27.06	1.03	.93	.63	.54
54	17.65	24.38	.85	.65	.48	.41
55	16.25	26.67	.62	.62	.33	.22
56	20.62	19.54	.43	.38	.09	.11
57	19.96	27.70	1.01	.89	.61	.59
58	19.99	22.90	.91	.54	.53	.33
59	18.80	25.35	.95	.60	.59	.34
60	18.80	17.25	.58	.43	.32	.17
Average	18.60	24.38	.87	.63	.51	.36
Grand Mean	21.69	21.78	1.12	.81	.75	.52
CV (%)	17.41	8.75	14.19	15.55	20.10	21.03
$s\bar{x}$	2.18	0.97	0.09	0.07	0.09	0.06
LSD (.05)	6.10	2.72	0.26	0.20	0.25	0.18
(.01)	8.07	3.59	0.34	0.27	0.32	0.23
(.001)	10.40	4.63	0.44	0.35	0.42	0.30

Appendix Table 2. (Continued) Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Fertility Index 1978	Fertility Index 1979	Yield (g) 1978	Yield (g) 1979
		Parents		
1	.76	.65	24.10	87.50
2	.77	.62	27.93	123.86
3	.49	.51	4.27	34.07
4	.81	.74	36.88	95.40
5	.65	.77	38.65	121.26
6	.82	.73	39.42	120.70
7	.77	.59	17.16	105.94
8	.79	.76	55.97	150.02
9	.67	.70	29.53	112.63
10	.71	.60	22.14	97.12
11	.61	.72	42.26	96.57
12	.80	.60	53.69	101.06
13	.74	.68	34.79	132.88
14	.83	.71	42.26	148.48
15	.75	.58	12.69	92.85
16	.62	.57	21.35	87.32
17	.70	.69	31.77	164.12
18	.75	.77	53.04	152.53
19	.69	.64	13.83	91.75
20	.78	.73	19.91	100.69
Average	.73	.67	31.08	111.09

Appendix Table 2. (Continued) Means, standard errors of the mean ($s\bar{x}$), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Fertility Index (g/g) 1978	Fertility Index (g/g) 1979	Yield (g) 1978	Yield (g) 1979
		OP		
21	.74	.68	35.50	112.76
22	.77	.61	35.68	131.02
23	.56	.51	42.26	75.22
24	.73	.70	28.90	133.37
25	.72	.67	48.67	130.57
26	.34	.54	21.04	50.99
27	.69	.68	24.32	115.14
28	.70	.68	40.16	147.83
29	.96	.69	47.36	100.99
30	.68	.62	23.59	65.21
31	.74	.66	41.82	133.14
32	.78	.68	41.59	118.43
33	.69	.72	30.47	124.91
34	.58	.63	30.41	115.50
35	.65	.59	17.37	106.89
36	.52	.55	19.74	84.51
37	.69	.69	35.86	127.70
38	.72	.74	41.17	134.13
39	.66	.67	22.87	117.69
40	.75	.69	34.05	130.71
Average	.68	.65	33.11	112.85

Appendix Table 2. (Continued) Means, standard errors of the mean (sx), coefficients of variation (CV,%), and the least significant differences (LSD) for eleven seed characteristics in a tall fescue parent-progeny nursery.

Entry Number	Fertility Index (g/g)		Yield (g)	
	1978	1979	1978	1979
		S_1		
41	.45	.49	6.27	39.14
42	.71	.60	10.50	52.18
43	.38	.42	3.21	20.53
44	.70	.68	10.68	109.42
45	.76	.71	26.64	81.95
46	.63	.57	11.02	33.05
47	.66	.60	5.95	28.95
48	.62	.62	10.82	44.16
49	.50	.59	10.76	43.56
50	.38	.32	1.85	18.24
51	.66	.51	10.00	42.75
52	.75	.55	16.87	37.88
53	.61	.59	11.56	64.75
54	.56	.59	15.35	95.70
55	.54	.35	4.85	18.48
56	.22	.21	1.76	23.53
57	.60	.66	18.86	70.30
58	.58	.59	9.53	49.16
59	.65	.56	12.31	58.41
60	.53	.46	11.95	101.68
Average	.57	.54	10.54	51.70
Grand Mean	.66	.62	24.91	91.88
CV (%)	17.92	10.24	26.04	34.47
$s\bar{x}$	0.07	0.04	3.75	18.29
LSD (.05)	0.19	0.10	10.49	51.29
(.01)	0.25	0.14	13.86	67.68
(.001)	0.33	0.17	17.86	87.23

Appendix Table 3. Main summary of analyses of variance for eleven seed characteristics in a tall fescue parent-progeny study, 1978 and 1979.

Source of Variation	Mean Squares[+]					
	Flag Leaf Area		Dry Wt. of 20 Flag Leaves		SFLW	
	1978	1979	1978	1979	1978	1979
Replications	40.10**	7.13*	0.75**	0.34	0.06	0.03
Entries	28.84**	17.76**	0.65**	0.48**	0.06**	0.15**
Among groups	155.28**	19.33**	2.54**	1.13**	0.07	0.04
Within groups	24.40**	17.70**	0.58**	0.45**	0.06**	0.16**
Parents	32.45**	31.51**	0.89**	0.73**	0.04	0.25**
OP	19.38**	5.11**	0.29**	0.21*	0.03	0.12*
S_1	21.38**	16.50**	0.56**	0.43**	0.11**	0.10
Error	2.86	2.06	0.07	0.12	0.03	0.07
	Girth		Stem Diameter		Panicle Length	
Replications	28.36**	958.82**	0.20**	0.18*	45.27**	1.85
Entries	16.58**	253.78**	0.24**	0.28**	56.22**	48.66**
Among groups	226.45**	4347.11**	0.46**	1.00**	193.70**	291.84**
Within groups	9.21**	110.15**	0.23**	0.26**	51.39**	40.13**
Parents	15.10**	139.66**	0.30**	0.34**	74.64**	57.06**
OP	6.68*	93.32*	0.17**	0.15**	34.03**	27.67**
S_1	5.86*	97.48**	0.23*	0.28**	45.51**	35.66**
Error[1]	3.44	45.57	0.04	0.04	3.23	2.38
	Panicle Area		Panicle Gross Wt.		Panicle Seed Wt.	
Replications	43.02	11.83*	0.19**	0.01	0.06	0.01
Entries	64.20**	41.91**	0.33**	0.16**	0.30**	0.11**
Among groups	431.58**	287.58**	2.77**	1.68**	2.64**	1.25**
Within groups	51.31**	33.29**	0.25**	0.10**	0.22**	0.07**
Parents	78.45**	53.42**	0.35**	0.17**	0.30**	0.09**
OP	29.88**	16.10**	0.17**	0.06**	0.18**	0.05**
S_1	45.61**	30.43**	0.22**	0.08**	0.17**	0.05**
Error[1]	14.26	2.83	0.03	0.02	0.02	0.01
	Fertility Index		Yield			
Replications	0.00	0.00	207.59**	2518.57		
Entries	0.05**	0.03**	638.11**	4695.40**		
Among groups	0.36**	0.31**	9358.28**	72715.65**		
Within groups	0.04**	0.02**	332.13**	2308.72**		
Parents	0.02	0.02**	623.14**	2646.00**		
OP	0.05**	0.01**	266.29**	1965.04**		
S_1	0.06**	0.04**	106.98**	2315.13**		
Error[1]	0.01	0.01	42.06	1003.284		

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

+ Degrees of freedom - replications, 2; entries, 59; among groups, 2; within groups, 57; parents, OP and S_1, 19; error, 118.

Appendix Table 4. Main summary of the combined analysis of variance for eleven seed characteristics in tall fescue over two years, 1978 and 1979.

Source of Variation	Mean Squares[+]			
	Genotypes	Parents	OP	S_1
	Flag Leaf Area			
Replications	34.10**	15.40*	13.25	7.45
Entries	33.53**	44.68**	15.02**	31.11**
Error (a)	2.87	2.37	4.09	2.349
Year	85.67**	4.46	177.12**	0.373
Year x Entries	13.07**	19.27**	9.47**	6.76**
Error (b)	2.23	3.05	2.18	1.46
	Dry Weight of 20 Flag Leaves			
Replications	1.05**	0.32	0.50	0.26
Entries	0.87**	1.14	0.39**	0.80**
Error (a)	0.10	0.09	0.13	0.09
Year	2.18**	0.61**	0.26	1.62**
Year x Entries	0.25**	0.48**	0.10	0.19**
Error (b)	0.09	0.09	0.13	0.04
	Specific Flag Leaf Weight			
Replications	0.01	0.15	0.02	0.00
Entries	0.13**	0.15**	0.08	0.16**
Error (a)	0.04	0.05	0.05	0.04
Year	6.02**	1.91**	2.52**	1.65**
Year x Entries	0.09*	0.14**	0.07	0.06*
Error (b)	0.05	0.05	0.08	0.03
	Girth			
Replications	635.91**	285.88**	284.89*	145.70*
Entries	183.05**	99.75**	60.61	67.70**
Error (a)	28.13	21.57	40.59	20.95
Year	78917.20**	33926.28**	33258.04**	14402.98**
	Stem Diameter			
Replications	0.12	0.16	0.06	0.01
Entries	0.45**	0.56**	0.25**	0.44**
Error (a)	0.05	0.05	0.05	0.04
Year	2.57**	1.21**	1.02**	0.45**
Year x Entries	0.07**	0.09	0.07*	0.07
Error (b)	0.04	0.05	0.03	0.04

Appendix Table 4. (Continued) Main summary of the combined analysis of variance for eleven seed characteristics in tall fescue over two years, 1978 and 1979.

Source of Variation	Mean Squares[+]			
	Genotypes	Parents	OP	S_1
	Panicle Length			
Replications	18.72**	3.96	8.47	6.97
Entries	95.23**	116.34**	57.85**	72.26**
Error (a)	3.18	3.20	3.91	2.70
Year	2.68	31.08**	0.53	3.91
Year x Entries	9.58**	15.36**	3.63	8.90**
Error (b)	2.87	2.57	3.24	2.76
	Panicle Area			
Replications	29.50*	7.90	17.11	11.84
Entries	88.39**	106.64**	32.97**	60.04**
Error (a)	8.69	12.49	7.12	6.97
Year	554.78**	199.49**	261.87**	110.04**
Year x Entries	17.73**	25.24**	12.93**	16.00*
Error (b)	8.68	13.56	4.34	8.15
	Panicle Gross Weight			
Replications	0.11**	0.03	0.13*	0.02
Entries	0.43**	0.43**	0.19**	0.25**
Error (a)	0.02	0.02	0.02	0.03
Year	8.15**	2.61**	4.02**	1.75**
Year x Entries	0.06**	0.09**	0.05*	0.05*
Error (b)	0.02	0.01	0.02	0.02
	Panicle Seed Weight			
Replications	0.05	0.02	0.02	0.04
Entries	0.35**	0.34**	0.20**	0.19**
Error (a)	0.02	0.02	0.02	0.02
Year	4.93**	2.20	2.26**	0.74**
Year x Entries	0.05**	0.05**	0.05**	0.04*
Error (b)	0.01	0.01	0.02	0.01
	Fertility Index			
Replications	0.00	0.01	0.03	0.01
Entries	0.07**	0.03**	0.04**	0.09**
Error (a)	0.01	0.01	0.01	0.01
Year	0.16**	0.10**	0.03	0.05**
Year x Entries	0.01	0.01	0.01	0.01
Error (b)	0.01	0.01	0.01	0.01

Appendix Table 4. (Continued) Main summary of the combined analysis of variance for eleven seed characteristics in tall fescue over two years, 1978 and 1979.

Source of Variation	Mean Squares[+]			
	Genotypes	Parents	OP	S_1
	Yield.			
Replications	9.77	3.44	1.60	6.84
Entries	40.27**	24.87**	14.25**	15.23**
Error (a)	5.62	7.02	6.05	4.28
Year	4028.72**	1912.49**	1906.58**	508.08**
Year x Entries	13.09**	7.94	8.00	8.99*
Error (b)	5.06	5.96	5.32	3.91

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

[+] Degrees of freedom when using genotypes, are- replications, 2; entries, 59; error (a), 118; year, 1; year x entries, 59; and error (b), 120. Using parents, OP and S_1, the degrees of freedom, replications, 2; entries, 19; error (a), 38; year, 1; year x entries, 19; and error (b), 40.

Appendix Table 5. [+]Simple correlation coefficients between eleven characteristics of tall fescue seed yield studied for two seasons - 1978 (upper diagonal) and 1979 (lower diagonal)[1].

Characteristics (all entries, n=60)	1	2	3	4	5	6	7	8	9	10	11
1. Flag Leaf Area	-	0.86	-0.23	0.41	0.52	0.55	0.56	0.63	0.55	0.35	0.54
2. Weight of 20 Flag Leaves	0.51	-	0.19	0.29	0.55	0.53	0.51	0.54	0.46	0.23	0.47
3. Specific Flag Leaf Weight	0.41	0.77	-	-0.08	0.16	0.03	-0.13	-0.07	-0.08	-0.13	-0.09
4. Girth	-0.64	-0.74	-0.46	-	0.39	0.47	0.56	0.63	0.56	0.41	0.75
5. Stem Diameter	0.80	0.63	0.47	-0.85	-	0.75	0.66	0.71	0.65	0.32	0.46
6. Panicle Length	-0.63	-0.71	-0.44	0.96	-0.84	-	0.72	0.67	0.57	0.24	0.51
7. Panicle Area	0.59	0.72	0.72	-0.56	0.60	-0.46	-	0.79	0.74	0.39	0.69
8. Panicle Gross Weight	0.72	0.82	0.65	-0.88	0.86	-0.87	0.78	-	0.93	0.59	0.83
9. Panicle Seed Weight	0.46	0.44	0.45	-0.21	0.44	-0.18	0.76	0.55	-	0.76	0.84
10. Fertility Index	0.08	-0.04	0.17	0.36	-0.04	0.36	0.31	0.00	0.74	-	0.63
11. Yield	-0.59	-0.68	-0.43	0.94	-0.78	0.90	-0.52	-0.81	-0.21	0.37	-

[+] Correlation coefficients calculated from means of 60 entries (n=60).

[1] The 0.05 and 0.01 significance levels (n=60) are 0.25 and 0.32, respectively.

Appendix Table 5. (Continued) [+]Simple correlation coefficients between eleven characteristics of tall fescue seed yield studied for two seasons - 1978 (upper diagonal and 1979 (lower diagonal)[1].

Characteristics (parents, n=20)	1	2	3	4	5	6	7	8	9	10	11
1. Flag Leaf Area	-	0.88	-0.06	0.27	0.48	0.37	0.52	0.59	0.47	0.00	0.40
2. Weight of 20 Flag Leaves	0.70	-	0.33	0.11	0.48	0.39	0.47	0.46	0.36	-0.09	0.32
3. Specific Flag Leaf Weight	0.46	0.74	-	-0.15	0.15	0.03	-0.10	-0.05	-0.04	-0.03	-0.04
4. Girth	-0.92	-0.76	-0.50	-	0.38	0.46	0.60	0.68	0.53	0.20	0.69
5. Stem Diameter	0.95	0.78	0.54	-0.96	-	0.72	0.73	0.71	0.67	0.03	0.37
6. Panicle Length	-0.91	-0.72	-0.47	0.93	-0.96	-	0.71	0.64	0.55	-0.19	0.38
7. Panicle Area	0.69	0.80	0.68	-0.74	0.72	-0.58	-	0.77	0.70	0.15	0.61
8. Panicle Gross Weight	0.91	0.84	0.65	-0.92	0.95	-0.91	0.82	-	0.89	0.24	0.78
9. Panicle Seed Weight	0.57	0.64	0.51	-0.51	0.56	-0.47	0.81	0.72	-	0.49	0.80
10. Fertility Index	-0.02	0.20	0.38	0.09	-0.03	0.06	0.30	0.19	0.61	-	0.45
11. Yield	-0.81	-0.66	-0.44	0.91	-0.85	0.83	-0.67	-0.80	-0.48	0.18	-

[+]Correlation coefficients calculated from means of 20 entries (n=20).

[1]The 0.05 and 0.01 significance levels (n=20) are 0.44 and 0.56, respectively.

Appendix Table 5. (Continued) [+]Simple correlation coefficients between eleven characteristics of tall fescue seed yield studied for two seasons - 1978 (upper diagonal) and 1979 (lower diagonal)[1].

Characteristics (OPs, n=20)	1	2	3	4	5	6	7	8	9	10	11
1. Flag Leaf Area	-	0.84	-0.65	0.10	0.44	0.60	0.59	0.61	0.64	0.64	0.63
2. Weight of 20 Flag Leaves	0.23	-	-0.19	-0.18	0.34	0.42	0.26	0.30	0.31	0.31	0.34
3. Specific Flag Leaf Weight	-0.63	0.25	-	-0.31	-0.25	-0.36	-0.76	-0.62	-0.71	-0.72	-0.65
4. Girth	-0.36	-0.01	0.23	-	0.21	0.21	0.09	0.26	0.26	0.35	0.36
5. Stem Diameter	0.32	0.56	-0.20	-0.24	-	0.76	0.39	0.67	0.55	0.31	0.53
6. Panicle Length	0.51	0.62	-0.23	0.00	0.80	-	0.55	0.57	0.40	0.19	0.54
7. Panicle Area	0.44	0.55	-0.25	-0.11	0.77	0.76	-	0.71	0.67	0.45	0.65
8. Panicle Gross Weight	0.33	0.37	-0.28	0.03	0.77	0.74	0.62	-	0.94	0.62	0.78
9. Panicle Seed Weight	0.20	0.19	-0.21	0.12	0.55	0.51	0.41	0.93	-	0.82	0.78
10. Fertility Index	-0.14	-0.20	0.01	0.23	-0.03	-0.03	-0.13	0.44	0.72	-	0.58
11. Yield	-0.14	-0.16	0.01	0.35	0.08	-0.08	-0.02	0.29	0.48	0.74	-

[+] Correlation coefficients calculated from means of 20 entries (n=20).

[1] The 0.05 and 0.01 significance levels (n=20) are 0.44 and 0.56, respectively.

Appendix Table 5. (Continued) [+]Simple correlation coefficients between eleven characteristics of tall fescue seed yield studied for two seasons - 1978 (upper diagonal) and 1979 (lower diagonal)[1].

Characteristics (S_1s, n=20)	1	2	3	4	5	6	7	8	9	10	11
1. Flag Leaf Area	-	0.84	-0.10	0.14	0.56	0.56	0.38	0.53	0.42	0.22	0.32
2. Weight of 20 Flag Leaves	0.80	-	0.34	0.18	0.66	0.60	0.42	0.50	0.38	0.09	0.32
3. Specific Flag Leaf Weight	-0.05	-0.27	-	0.23	0.41	0.29	0.09	0.17	0.16	0.04	0.22
4. Girth	-0.29	-0.02	-0.75	-	0.30	0.23	0.21	0.20	0.19	0.17	0.34
5. Stem Diameter	-0.01	-0.24	0.99	-0.77	-	0.75	0.65	0.73	0.67	0.35	0.44
6. Panicle Length	0.35	0.61	-0.81	0.49	-0.79	-	0.72	0.64	0.55	0.33	0.39
7. Panicle Area	0.44	0.33	0.51	-0.53	0.55	0.03	-	0.66	0.58	0.16	0.44
8. Panicle Gross Weight	-0.02	-0.25	0.99	-0.77	0.99	-0.79	0.55	-	0.91	0.57	0.76
9. Panicle Seed Weight	0.34	0.24	0.41	-0.36	0.44	-0.01	0.79	0.45	-	0.81	0.86
10. Fertility Index	0.27	0.30	-0.39	0.30	-0.37	0.51	0.15	-0.36	0.50	-	0.70
11. Yield	-0.27	-0.12	-0.37	0.64	-0.38	0.26	-0.16	-0.37	0.22	0.65	-

[+]Correlation coefficients calculated from means of 20 entries (n=20).

[1]The 0.05 and 0.01 significance levels (n=20) are 0.44 and 0.56, respectively.