AN ABSTRACT OF THE THESIS OF

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(Name) (Degree) (Major)

Date thesis is presented December 6, 1963

Title A COMPARISON OF PROGENY TESTING METHODS AND ESTIMATES OF COMBINING ABILITY FOR SEED YIELD AND ASSOCIATED VARIABLES IN TALL FESCUE (*FESTUCA ARUNDINACEA*, SCHREB.)

Redacted for Privacy

Abstract approved
(Major Professor)

Eight genotypes of tall fescue were selected from a plant population consisting of 9000 individuals. Selection was based on early maturity, self-sterility, seed and forage potential, and nutritive value.

Parental clones, single cross, open pollinated, self pollinated and polycross seeds were organized into a randomized block experiment with five replications each of which contained 63 entries with ten plants to the entry. The distance between entry rows was three feet; plants within the entry were planted one foot apart. The experimental nursery was planted on October 11, 1961, at the Hyslop Agronomy Farm, Corvallis, Oregon. Alta and Kentucky 31 varieties were used as checks. Parchment bags were used to secure

information on self sterility and seed production. Height, maturity, disease incidence, number of culms per plant, panicles not harvested and forage yield were also evaluated. Griffing's model 1, experimental method 4, was used to test both general and specific combining ability. Simple correlation coefficients were calculated to measure the association between characters and between progeny testing methods within characters.

The height of F_1 progenies was positively correlated with the height of both the mean of the parents and the largest parent. Height was also correlated with the number of culms per plant and the stage of maturity before harvesting.

The stage of maturity of the single crosses was positively correlated with the stage of maturity of both the mean of the parents and the largest parent. Either polycross or open pollination may be used for evaluating maturity with comparable results.

Although there was an incidence of *Helminthosporium dyctioides*, it was not serious enough to affect markedly the general performance of the plants in the nursery.

The number of culms per plant for single crosses was negatively correlated with the number of culms for both the mean of the parents and the smallest parent. The number of culms per plant was also correlated with seed yield. From parents to S_1 there was a reduction in the number per plant.

When open pollinated seed was bagged, the seed yield of the F_1 was positively correlated with the one of the smallest parent. Under natural conditions, F_1 open pollinated seed was not correlated with either one of the parent OP seed. In both cases, however, open pollinated seed was positively correlated with self pollinated seed.

Inbreeding, from parents to S_1, increased the percentage of self fertility.

The evaluation of the number of panicles not harvested revealed that seed setting was not uniform among the plants in the nursery.

F_1 forage yield was correlated with the forage yield of the mean of the parents as well as the one for both the largest and the smallest parent. Forage yield was independent from the other characters measured.

The checks, Alta and Kentucky 31, behaved remarkably similarly, since they differed only in one out of the nine characteristics measured.

Except for the visual ratings of disease and panicles not harvested, the characters measured in this experiment responded significantly to the effects of general combining ability.

Seed yield, as estimated from either a row basis or an enclosed panicle basis, responded to both general and specific combining ability.

The comparison of progeny testing methods showed that there was no complete agreement in their ability to determine general combining ability. Yet, all the methods were equally effective in selecting the best combiner, parent 342, and, in general, permitted one to roughly separate at least two categories of good and poor combiners.

Open pollination as a progeny testing method, if properly used, would permit an economic and effective screening of the original material on a large number of genotypes.

A COMPARISON OF PROGENY TESTING METHODS AND ESTIMATES OF COMBINING ABILITY FOR SEED YIELD AND ASSOCIATED VARIABLES IN TALL FESCUE (*FESTUCA ARUNDINACEA*, SCHREB.).

by

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A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

DOCTOR OF PHILOSOPHY

June 1964

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Date thesis is presented Dec. 6, 1963

Typed by Bernice Cáceres

ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Dr. R. V. Frakes for his assistance, guidance and counseling throughout this experiment; to Drs. J. R. Cowan and Ralph Bogart for the careful reading of the manuscript; and to Dr. S. P. Sinha for his invaluable help in the statistical interpretation.

Appreciation is extended to Mr. Lewis C. Johnson and fellow graduate students participating in the Forage Breeding project for their effective and valuable collaboration in all phases of field and laboratory work.

The author is also grateful to the Farm Crops Department for making land and facilities available for this study.

Finally, recognition is also given to Dr. L. V. Crowder, the Rockefeller Foundation, and the Department of Agricultural Investigations (D. I. A.) of the Colombian Ministry of Agriculture for making possible the trip to the United States as well as the financial help for both Master and Ph. D. work.

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INTRODUCTION

Tall fescue (*Festuca arundinacea*, Schreb.) is a very important seed and forage crop in Oregon, one of the leading tall fescue seed producing states. In 1962, Oregon produced over 4 million pounds of certified seed in an area of 5,172 acres with an average of 787 pounds per acre. Its importance is, however, not limited to the State of Oregon, for tall fescue is one of the most prominent forage crops in the United States, as well as in several other countries located within the temperate zone. One of the main reasons for its widespread use is its remarkable adaptation to different environments.

Despite its wide importance, adaptation and use, very little is known about some of the phases of its breeding behavior. Success in breeding for new improved forage varieties is often dependent on the type of progeny testing used to evaluate parental genotypes. This is one of the reasons why forage breeders are constantly comparing different methods and, in this respect, tall fescue is no exception.

Another common problem is the way selection for one character may affect the expression of other agronomic characters. Association studies may prove of great usefulness in trying to solve this type of problem.

Progress in selection is conditioned by the extent the plant is affected by the environmental influence. This is one of the reasons why the use of heritabilities, both narrow and broad sense, is so especially helpful in those characters, the expression of which is conditioned by many genes. Gene action determines to a great extent the right choice of method in the breeding approach.

The present experiment was designed to examine the following objectives:

1. To compare the efficiency of different methods of progeny testing.
2. To study the association between seed and forage yield with other measurable variables: height, stage of maturity, number of culms per plant and self sterility.
3. To determine the nature of the gene action governing the above-mentioned variables as indicated by heritability and combining ability estimates.

REVIEW OF LITERATURE

Great differences exist between tall fescue varieties and genotypes in ability to produce seed and forage (Cowan 12, p. 74). Forage characteristics also vary widely in this species (13, p. 306). Some plants produce an upright type of growth whereas others produce a lax type of leaf that drops to the ground. Frakes (21, p. 53) found differences between 20 genotypes of tall fescue in their ability to produce dry matter and crude protein. These differences were found to exist when the genotypes were allowed to express themselves, but when retarded, the genotypes approached an equilibrium resulting in no differences between them.

In tall fescue, there is approximately a ten-day period after the panicles have emerged in which selection and bagging of panicles can be done before there is any danger of flowering whether plants are of early or late maturity. The number of days to complete flowering is about the same for any plant (Cowan 12, p. 73).

Cowan (13, p. 305) stated that there was a great potential for increasing seed production in tall fescue. The amount of seed produced per panicle appears to be a better indication of the seed production of a plant than the number of culms it contains. It is possible to select for high seed yield and high forage yield at the same time. Caceres (10, p. 41) did not find significant differences in self seed yield among early, intermediate and late maturity groups. For the same groups, differences in height were found to be significant.

On the basis of a three-year study, Cowan (12, p. 26) concluded that tall fescue was highly self-sterile. The most common serious diseases on this species have been caused by *Helminthosporium* and *Rhizoctonia*.

Polycross progenies of the 56-chromosome tall fescue x annual ryegrass plants were studied in the greenhouse for certain morphological characters distinguishing the ryegrass or fescue plant. Various random combinations of ryegrass and tall fescue characters were expressed in the progenies. Buckner *et al*. (6, p. 75) suggest the possibility of developing new forms that combine the palatability and nutritive qualities of ryegrass with the adaptation of fescue.

Buckner (5, p. 177-180) used observational techniques to develop inbred lines of tall fescue of improved palatability in each generation of inbreeding by rotating plants according to the intensity of grazing after the spaced plant nurseries were repeatedly grazed with cattle. The two techniques used were satisfactory for differentiating breeding materials of tall fescue for palatability.

A study of heritability by Burton and DeVane (9, p. 478-481) in replicated clonal material of tall fescue indicated a potential increase of 33 and 162 percent for forage and seed yield respectively, over that of the population mean, may be obtained if proper selection methods were used.

Caceres (10, p. 43) found estimates of heritability in narrow sense in tall fescue for maturity and self-seed yield of 0.19 and 0.46, respectively. Additive gene effects appeared relatively more important than non-additive gene effects.

Tsiang (43, p. 508-522) investigated the relationship between clones of Bromus inermis and their S_1 progenies for hay yield, basal diameter, recovery, leaf width and drought resistance. Significant positive correlations were found in most comparisons, except those for leafiness and number of culms.

MacDonald (39, p. 20-25) found that in Bromus inermis parent progeny correlations for all characters were consistently higher between parents (So) and open pollinated (OP) progenies than between parents (So) and self pollinated (S_1) progenies. The correlations for yield were too low for prediction purposes whereas those for characters such as height, vigor and spread generally were greater and more consistent.

The parent-progeny relationship in Bromus inermis was studied by Hawk and Wilsie (29, p. 112-118) for the So, S_1 and S_2 generations. A relatively low heritability for yield was found, but there was an indication that the regression was somewhat greater as the degree of inbreeding increased.

The regressions of open-pollinated progenies on parents in *Bromus inermis* reported by Knowles (37, p. 15-19) estimate heritabilities to be high for creeping habit, moderate for forage production and low for seed yield.

Parent progeny correlations between So clones and their inbred progenies for vigor, panicle production and leafiness generally were inconsistent and low in non-replicated nurseries as reported in studies of *Dactylis glomerata* by Kalton *et al*. (34, p. 481-482). In replicated tests, all correlations, including those for yield, were highly significant. It was also reported that estimates of heritability for panicle number and forage yield were negative or low, while those for height, leafiness and spring vigor were considerably higher.

Weiss *et al*. (45, p. 594-606) found that clonal performance in *Dactylis glomerata* was significantly correlated with that of open-pollinated progenies for vigor, panicle number and winter survival, but not for forage yield or leafiness.

Differences between reciprocal crosses were of some importance in perennial ryegrass, but no dominance effects were observed by Fejer (18, p. 86-103). Inbreeding depression was studied in different plants and characters. In spite of differential inbreeding influences, positive correlations were found between different groups of selfed plants in both overall means and maternal means of crosses. Tiller number/tiller weight relationship proved to be useful for differentiating parents in perennial ryegrass (18, p. 86-103).

In sand blue stem, Kneebone (36, p. 459-461) obtained fair agreement for heritability estimates derived in three ways: variance component for clonal data, variance components from open pollination progeny data, and parent-progeny regression. Characters studied were plant height, plant diameter, leafiness, and protein percentage in the leaves. Considerable genetic potential was indicated for all characters, with height most heritable, and protein percentage least heritable.

Davis (14, p. 572-576) found that correlation coefficients for yield between S_1 alfalfa progenies and polycross progenies were significant when similar methods of planting were used. Nevertheless, the yields in the spaced polycross nursery were significantly correlated with the yields in the row seeded polycross nursery.

Wilsie (46, p. 786-794), in studying eight F_1 alfalfa progenies, found that crossing plants for high self fertility resulted in F_1 progenies of high self fertility, while crossing plants of low self fertility resulted in F_1 progenies of relatively low self-fertility.

Adams and Semeniuk (1, p. 677-679) found that estimates of heritability based on family differences in reaction to Pseudopezisa medicaginis ranged from 79.26 to 89.62 percent in two unrelated alfalfa populations. The heritability of individual differences was lower, amounting to 27.4 percent in the one population for which it was calculated. Excellent agreement was obtained among four estimates of genetic variance for leaf spot reaction in the case of one population.

Heritabilities for spring and fall growth habits, rate of recovery, and forage yield were 71, 58, 85 and 58 percent as found by Kehr (35, p. 53-55).

Seedling vigor and fall growth habit of the 91 diallel crosses among 14 alfalfa clones raised in 3 and 4 states, respectively, were scored. Estimated variance components for general (by far the largest component) and specific combining ability and the interaction of these with locations were all highly significant for both characters. Clones differed in their contributions to both additive and non-additive genetic variances. The two characters were highly correlated, and interlocation correlations for each character were likewise high (Carnahan 11, p. 511-516).

Frakes et al. (22, p. 210-212) found that the diallel analysis for general and specific combining ability in alfalfa showed that natural height and longest stem measurement responded to the effects of general combining ability, whereas natural width and number of stems per plant were low in their response to the effects of general combining ability. Dry matter yield was intermediate among the four measurable components in relation to general combining ability response. These findings were substantiated by squared parent-offspring correlation coefficients.

Also in alfalfa, the estimated variance component for general combining ability was slightly larger than that for specific combining ability for fall growth habit and rate of recovery (Kehr 35, p. 53-55). The estimated variance component for specific was much larger than that for general combining ability for forage yield and spring growth habit. Thus, additive appeared more important than non-additive gene action in determining differences in fall growth habit and rate of recovery, but forage yield and spring growth habit differences were determined more by non-additive gene action.

Heritability values as measured by the regression of S_1 progenies on So parental plants in sweet clover were higher for habit of growth than for plant vigor (32, p. 120-125).

It is of great interest to the breeder to know to what extent the different characters for his plant material are inherited independently of one another. If they are correlated, what is the degree of correlation and is it positive or negative? In other words, will selection for one character in a positive direction change the frequency of types of the plant population with regard to the other characters in a positive or negative direction? (Frandsen 23, p. 306-313; Torrie 42, p. 451). Positive genotypic correlations between characters which can be selected for in early generations and those which can not be readily selected for until later generations can result in an improvement in traits such as yielding ability. Negative genotypic correlations could result in the deterioration of certain characters not under selection. In cross-fertilized forage species, a negative correlation between seed setting and other characters could result in a deterioration of an improved variety, since natural selection often favors plants that set the most seeds and once a new forage is released it is subjected to natural selection (Torrie 42, p. 451).

MATERIALS AND METHODS

Source of Material

Eight genotypes selected from 9,000 plants constituted the parental material. Selection was based on early maturity, self-sterility, seed and forage potential, and nutritive value on the basis of crude protein and chromogen content (Table 1).

The seed of each single cross (Sx) used in the present experiment was obtained from single cross blocks in which each parent included in the cross was increased vegetatively and planted in paired rows of eight propagules to facilitate the controlled natural cross pollination after enclosing unemasculated inflorescence in the same parchment bag.

Open pollinated (OP) seed was obtained from unbagged panicles of each parent plant whereas self-pollinated (S_1) seed came from panicles which were bagged before blooming.

Polycross (Px) seed was collected from isolated nurseries including the eight original parents.

Seeds harvested and designated OP, Px, Sx, and S_1 were planted in flats filled with perlite, subjected to cold treatment (7 days at 38-39° F) to break dormancy, and then taken to the greenhouse. When the seedlings reached a height of one or two inches, they were

Table 1. Identification of the eight tall fescue parent clones used for various progenies tested.

Culture	Flowering Date - May[1]	Chromogen[2]	% Crude Protein[2]	Seed Yield Grams[3]	% Self Fertility[4]	Origin
304	20	140	9.89	2.57	9.7	Goar
314	14	121	8.65	1.76	7.0	Goar
315	19	130	10.34	2.62	6.4	Goar
339	18	115	8.42	3.40	12.0	S-170
340	16	123	9.43	2.96	2.9	S-170
342	16	140	8.55	3.49	5.2	S-170
351	20	125	8.15	3.83	8.3	S-170
352	20	138	8.73	3.93	7.4	S-170

[1] 1957-58 average [2] Clippings made 7-10 through 7-24-57 [3] Five panicle samples, 1955
[4] Comparison of open vs. self pollinated seed set.

individually placed in 1.75 x 1.75 x 2 inch plantbands filled with a mixture of soil and peat moss. Clones taken from the original parent plants were also individually placed in the same type of plantband. The varieties Alta and Kentucky 31 were used as checks.

A liquid fertilizer application was used to prevent transplant shock. The seedlings were clipped and kept weed free.

Establishment

On October 11, 1961, the seedlings and the propagules were transplanted in the experimental field at the Hyslop Agronomy Farm, Corvallis, Oregon. The experiment consisted of a simple randomized block design with five replications organized into ranges containing 45 rows plus one border row at each end of the range. The distance between rows was three feet and the distance between plants one foot. There were ten plants to the row. Two orchardgrass plants per row were planted between the ranges (within the alley) to offset the border effect. Spacing was sufficient to permit adequate cultivation and maintenance throughout the experimental period.

Missing plants were replaced by new ones kept on reserve in the greenhouse. Orchardgrass seedlings were transplanted on November 18, 1961.

An application of 250 lbs./acre of ammonium nitrate was applied on April 9, 1962.

Measurements

Self-Fertility and Seed Production. Wooden poles, six feet long, were placed by every other plant (five to the row). On May 24-30, 1962, bagging for self-fertility started. For this purpose, five plants per row were used and three panicles per plant were bagged. The bags were tied top and bottom with aluminum wire of .0032 inch diameter. The tie to the stake was in the form of a loop to allow the bags to move as the culm grew in length.

One month later, June 25-30, 1962, using the procedure outlined above, bagging was started for open pollinated panicles. Three panicles of comparable size from each of the plants already selfed were enclosed in parchment bags. These bags were used to avoid shattering and to calculate the percentage of self-fertility according to the formula,

$$\frac{\text{weight of seeds set per panicle under bag}}{\text{weight of seeds set per panicle in the open}} \times 100.$$

Bags were used not only to enclose the remainder of the panicles in the plants used for self-sterility, but also for the rest of the plants in the row. The bagging procedure covered only the first two replications of the experiment in contrast to five replications for the self-sterility study.

Height. Height was measured in centimeters (cm.) from the ground level to the average of the two or three highest panicles on May 4 to 10, 1962.

Maturity. Each plant was scored for maturity on a scale from one to nine on May 4 to 10, 1963. These ratings were as follows: 1, no panicles; 2, 3, 4, one to several panicles formed but not visible; 5, few, small panicles; 6, 7, 8, few to several panicles completely developed; 9, some panicles at the stage of anthesis.

Disease Rating. All plants in the nursery were rated for incidence of disease on the basis of the number of spots according to the following rating: 0, no lessions; 1, 0-5% leaf spots; 2, 6-25% leaf spots; 3, 26-50% leaf spots; 4, 51-100% leaf and stem spots; 5, dead.

Number of Culms. For each plant on the nursery, the number of culms was counted by hand and this counting lasted from June 14 to June 20, 1962. Only those culms bearing panicles were taken into account.

Harvesting. From July 1 to July 3, the last three replications were harvested by hand on a row basis except for those culms bearing bags for self-sterility studies. All the panicles were enclosed into paper bags and stored for threshing.

From July 5-7, 1962, all bags containing self and open pollinated seeds were harvested. Bundles were made to keep together all bags belonging to the same row.

Threshing. Each bag was harvested and threshed separately in a small friction type thresher and cleaned by means of a hand screen and a South Dakota Seed Blower with a gate opening of 20.

Weighing. The seeds intended to be used for self-sterility purposes were weighed in an automatic scale with a precision of one ten-thousandth of a gram. The rest of the seeds were weighed to the nearest gram on a Toledo scale.

Panicles not Harvested. After seed harvest, July 7, 1962, an evaluation was made in order to determine the extent of the immature panicles not harvested. The following scale was used: 0, plant unharvested; 1, 76 to 100% panicles unharvested; 2, 51-75% panicles unharvested; 3, 26 to 50% panicles unharvested; 4, 1-25% panicles unharvested; 5, all panicles harvested.

Forage. To examine recovery of the plants after seed harvest, herbage from the whole experiment was cut at a height of two inches. Herbage was clipped and bagged again on September 8-10, 1962, on a row basis. The dry weight was recorded on a Toledo scale to the nearest gram after the samples were oven-dried at 160° F.

Statistical Analysis. Ordinary analysis of variance was performed for each one of the characters measured. Comparisons between entries, between and within progeny testing methods, were made by using the partition of degrees of freedom as explained by Li (38, p. 226). The diallel analysis, model I, experimental method 4, as explained by Griffing (26, p. 463-493) was used to test both general and specific combining ability (Table 3).

In using this approach, it was assumed that the use of a statistical technique developed for diploid organisms would yield information on general and specific combining ability in tall fescue, an allohexaploid species. It is also assumed that the variables are fixed, that epistasis is absent, and the parent plants were equally heterozygous. General combining ability, as defined by Johnson (31, p. 327-334) is here interpreted as the relative performance due primarily to the additive effects of polygenes, whereas specific combining ability is interpreted as the relative performance due primarily to deviations from the additive scheme. The combining ability analysis was also used to calculate both broad and narrow sense heritability estimates according to the formulas:

$$\text{Broad sense heritability} = \frac{2\hat{\sigma}_g^2 + \hat{\sigma}_s^2}{2\hat{\sigma}_g^2 + \hat{\sigma}_s^2 + \hat{\sigma}^2}$$

Table 2. Identification numbers used for the single crosses.

Parent	304	314	315	339	340	342	351	352
304	--	39	40	45	46	51	52	57
314		--	58	63	64	62	59	56
315			--	53	50	47	44	41
339				--	38	37	42	43
340					--	48	49	54
342						--	55	60
351							--	61
352								--

Table 3. Expected mean squares in the analysis of variance for general (GCA) and specific (SCA) combining ability, model I.

Source of Variation	d. f.	Expected Mean Squares
GCA	p - 1	$\sigma^2 + n(p-2)\sigma_g^2$
SCA	p(p - 3)/2	$\sigma^2 + n\sigma_s^2$
Error	m	σ^2

Where p = Number of parents n = Number of replications

m = Degrees of freedom of experimental error

σ_g^2 = Variance for general combining ability

σ_s^2 = Variance for specific combining ability

σ^2 = Error mean square

$$\text{Narrow sense heritability} = \frac{2\hat{\sigma}_g^2}{2\hat{\sigma}_g^2 + \hat{\sigma}_s^2 + \hat{\sigma}^2}$$

where $\hat{\sigma}_g^2$ = observed variance for general combining ability

$\hat{\sigma}_s^2$ = observed variance for specific combining ability

$\hat{\sigma}^2$ = observed error mean square

With the exception of disease rating and the number of panicles not harvested, all possible simple correlation coefficients were calculated between the rest of the characters measured on the single cross data. All possible correlation coefficients were also calculated within each character for progeny testing methods. The relationship between mean of the parents vs. single crosses, largest parent vs. single crosses, and smallest parent vs. single crosses, within each character measured, was also estimated by means of correlation coefficients.

RESULTS

Height

Except for checks, all the differences between entries, between and within progeny testing methods, were significant at the one percent level (Table 4). The greatest height (69.44 cm.) corresponded to the single crosses and the smallest (42.97 cm.) to the checks (Table 5). The mean of the S_1 plants (54.97 cm.) was smaller than the mean of the parents (65.08 cm.).

The height of the single crosses ranged from 57.6 to 81.3 cm. (Table 7). For the polycross, the height ranged from 55.7 to 74.8 cm. (Table 6). The S_1 progenies ranged from 38.9 to 69.7 cm.; the OP, from 51.3 to 65.3 cm.; and the parents, from 38.5 to 83.0 cm. Thus, the largest range of variability for height between the progeny testing methods corresponded to the single crosses and the smallest to the open pollination. However, the range of variability for height of the parents by far exceeded the ones shown by the progeny testing methods (Table 6).

The simple correlation coefficients between methods (Table 8) indicate that the height of the single crosses is associated with the height of the mean of the parents (r = 0.40*) and the height of the largest parent (r = 0.49**) but not with the height of the smallest parent. There

Table 4. Analysis of variance for plant height (cm.) in tall fescue.

Source of Variation	SS	d. f.	MS	F
Replications	5398.56	4	1349.6400	28.37**
Entries	36365.05	61	596.1483	12.53**
Among groups	14905.18	5	2981.0360	7.78**
Within groups[1]	21459.87	56	383.2119	8.05**
Checks	48.84	1	48.8400	1.03
Single crosses	6741.95	27	249.7018	5.25**
Polycrosses	1550.89	7	221.5557	4.66**
Selfed	3559.32	7	508.4743	10.69**
Open pollinated	955.60	7	136.5143	2.87**
Parents	8603.28	7	1229.0400	25.83**
Error	11606.75	244	47.5686	---
Total	53370.36	309	----	---

[1] Used as error term to calculate F for among groups

** Significant at the 1% level

Table 5. Mean height values in cm. for checks and different methods of progeny testing[1] in tall fescue, as recorded on May 4-5, 1962.

Entries	Height cm.
Checks	42.97
Sx	69.44
Px	66.41
S_1	54.97
OP	55.67
Parents	65.08

[1] Sx = single crosses Px = polycrosses S_1 = selfed
OP = open pollination

was no correlation between the height of the parents and the height of the polycross, self and open pollinated progenies. The height of the polycross progenies was also independent from the height of both self and open pollinated progenies (Table 8).

The combining ability analysis (Table 9) indicated significance for general combining ability but not for specific combining ability. This indicates that height is controlled primarily by an additive gene system.

The effects and variances due to general combining ability (Table 10) indicate that parent 340 had the largest combining ability, whereas parent 315 had the lowest.

Table 6. Mean height of tall fescue progenies[1,2] in cm., as recorded on May 4-5, 1962.

Parent Identification	Progeny Testing Methods Px	S_1	OP	Parent
304	69.6	48.9	61.2	66.2
314	74.8	66.0	65.3	83.0
315	62.2	38.9	51.8	69.4
339	55.7	53.3	53.7	61.2
340	73.1	60.4	57.8	84.4
342	69.4	69.7	52.8	48.7
351	59.9	48.4	51.5	69.2
352	66.7	54.0	51.3	38.5

[1] Px = polycross S_1 = selfed OP = open pollination

[2] Average height of the checks: Alta = 40.8 cm.
Kentucky 31 = 45.2 cm.

Maturity

As indicated in Table 11, there were significant differences (1% level) for entries and for both between- and within-progeny testing methods. Checks were not significantly different.

The largest mean value for maturity (8.35) corresponded to the single crosses and the lowest (5.54) to the checks. There was no apparent inbreeding depression between the parents (7.97) and the S_1's (7.57). In fact, polycrosses, open pollination and the parents

Table 7. Mean height in cm. of tall fescue single crosses as recorded on May 4-5, 1962.

Parents	304	314	315	339	340	342	351	352	Total
304	---	60.60	64.38	61.82	73.10	68.96	62.88	59.14	450.88
314		---	64.20	68.14	80.66	81.30	77.90	66.52	499.32
315			---	66.34	74.58	75.88	67.98	69.82	483.18
339				---	71.50	73.64	62.28	57.58	461.30
340					---	78.48	78.48	75.00	531.80
342						---	77.42	75.38	521.06
351							---	60.50	487.44
352								---	453.94

Table 8. Simple correlation coefficients (r) between different progeny testing methods for height in tall fescue.

	r	n[1]
Single crosses vs. mean of the parents	0.40*	28
Single crosses vs. largest parent	0.49**	28
Single crosses vs. smallest parent	0.21	28
Polycross vs. selfed	0.60	8
Polycross vs. OP	0.69	8
Polycross vs. parents	0.31	8
Selfed vs. OP	0.38	8
Selfed vs. parents	-0.01	8

* Significant at the 5% level ** Significant at the 1% level

[1] n = number of paired observations

Table 9. General (GCA) and specific (SCA) combining ability analysis for height in tall fescue single crosses.

Source of Variation	SS	d.f.		MS	F
Replications	3697.85	4		924.46	19.56**
Single crosses[1]	6741.95	27		249.70	5.28**
GCA	5321.28		7	760.18	16.08**
SCA	1420.63		20	71.03	1.50
Error	5105.21	108		47.27	---
Total	15545.01	139		---	---

** Significant at the 1% level

Table 10. Estimates of general combining ability effects and variances for height in tall fescue single crosses.

Parents	General Combining Ability	
	Effects	Variances
304	-5.8725	33.1075
314	2.2008	3.4648
315	-0.4892	-1.1394
339	-4.1358	15.7261
340	7.6142	56.5973
342	5.8242	32.5426
351	0.2208	1.3300
352	-5.3625	27.3777

were very close in their maturity stage (Table 12).

The range of variability for single crosses was from 7.44 to 8.92 (Table 14); for polycrosses, from 6.7 to 8.8; for S_1's, from 6.2 to 8.4; for open pollination, from 7.0 to 8.1; and for parents, from 6.0 to 9.0. Thus, the highest range of variability for maturity corresponded to the parents and the lowest to the single crosses. The ranges for Px, S_1 and OP were very close to one another (Table 13).

The maturity in single crosses was associated both with the mean of the parents (r = 0.37*) and the largest parent (r = 0.44*),

Table 11. Analysis of variance for maturity rating in tall fescue.

Source of Variation	SS	d. f.	MS	F
Replications	16. 58	4	4. 1450	18. 59**
Entries	217. 37	61	3. 5634	15. 99**
Among groups	90. 84	5	18. 1680	8. 04**
Within groups[1]	126. 53	56	2. 2594	10. 14**
Checks	0. 57	1	0. 5700	2. 56
Single crosses	23. 51	27	0. 8707	3. 91**
Polycrosses	14. 18	7	2. 0257	9. 09**
Selfed	25. 98	7	3. 7114	16. 65**
Open pollinated	5. 69	7	0. 8128	3. 64**
Parents	56. 60	7	8. 0857	36. 27**
Error	54. 40	244	0. 2229	---
Total	288. 35	309	---	---

[1] Used as error term to calculate F for among groups

** Significant at 1% level

but not with the smallest parent. A significant association ($r = 0.71^*$) was also observed between the maturity of the polycrosses and that of open pollinated progenies, thus, suggesting that either one would lead to comparable results in estimating maturity (Table 15).

Table 12. Mean maturity[1] values for checks and different methods of progeny testing[2] in tall fescue, as recorded on May 4-5, 1962.

Entries	Maturity Rating
Checks	5.54
Sx	8.35
Px	8.04
S_1	7.57
OP	7.61
Parents	7.97

[1] Scale ranking from 1 = no panicles to 9 = some panicles at anthesis

[2] Sx = single crosses Px = polycrosses OP = open pollination S_1 = selfed

A significant value for general combining ability ($F = 14.23^{**}$ Table 16) indicates that maturity responds primarily to additivity.

The information shown in Table 17 indicates that parent 340

Table 13. Average stage of maturity of tall fescue progenies rated[1] on May 4-5, 1962.

Parent Identification	Progeny Testing Methods[2, 3] Px	S_1	OP	Parents
304	8.3	7.4	7.9	8.3
314	8.4	8.4	8.1	9.0
315	8.0	6.2	7.4	8.9
339	6.7	7.9	7.2	8.4
340	8.8	8.4	8.1	9.0
342	8.5	8.4	7.6	6.0
351	7.8	6.6	7.0	8.3
352	7.9	7.2	7.5	6.0

[1] Scale ranging from 1 = no panicles to 9 = some panicles at anthesis

[2] Px = polycrosses S_1 = selfed OP = open pollination

[3] Average maturity for checks: Alta = 5.3
Kentucky 31 = 5.8

Table 14. Mean stage of maturity[1] for tall fescue single crosses, as recorded on May 4-5, 1962.

Parents	304	314	315	339	340	342	351	352	Total
304	---	8.1	8.3	8.2	8.7	8.4	8.0	7.4	57.1
314		---	8.3	8.4	8.9	8.6	8.6	8.0	58.9
315			---	8.4	8.8	8.6	8.4	8.2	59.0
339				---	8.9	8.5	8.0	7.6	58.0
340					---	8.9	8.7	8.7	61.6
342						---	8.7	8.0	59.7
351							---	7.4	57.8
352								---	55.3

[1] Scale ranging from 1 = no panicles to 9 = some panicles at anthesis

Table 15. Simple correlation coefficients (r) between different methods of progeny testing for maturity in tall fescue.

	r	n[1]
Single crosses vs. mean of parents	0.37*	28
Single crosses vs. largest parent	0.44*	28
Single crosses vs. smallest parent	0.28	28
Polycross vs. selfed	0.26	8
Polycross vs. OP	0.71*	8
Polycross vs. parents	-0.04	8
Selfed vs. OP	0.61	8
Selfed vs. parents	-0.19	8
OP vs. parents	0.22	8

* Significant at the 5% level

[1] n = number of paired observations

Table 16. General (GCA) and specific (SCA) combining ability analysis for maturity in tall fescue single crosses.

Source of Variation	SS	d.f.		MS	F
Replications	6.3953	4		1.598825	7.92**
Single crosses	23.5140	27		0.8709	4.31**
GCA	20.0980		7	2.8711	14.23**
SCA	3.4160		20	0.1708	0.85
Error	21.8007	108		0.2018	---
Total	51.7100	139		---	---

** Significant at the 1% level

Table 17. Estimates of general combining ability effects and variances for maturity in tall fescue single crosses.

	General Combining Ability	
Entry	Effects	Variances
304	-0.2308	0.0474
314	0.0858	0.0015
315	0.0858	0.0015
339	-0.0775	0.0001
340	0.5358	0.2812
342	0.2092	0.0379
351	-0.1042	0.0049
352	-0.5042	0.2483

had the highest combining ability and parent 339 the lowest.

Disease Incidence

The information on this character is presented in Tables 18 through 20. There were no significant differences between progeny testing methods for disease incidence. Likewise, there were no differences between checks or open pollinated progenies. The differences between single crosses, polycrosses and parents were significant at the one percent level (Table 18).

The effect of the disease, *Helminthosporium dictyoides*, was less than 25 percent over the whole experiment. In other words, the disease did not impair significantly the overall performance of the nursery.

Number of Culms

With the exception of the checks, the difference between entries and between and within progeny testing methods were significant at the one percent level (Table 21) for number of culms per plant.

The largest mean number of culms (24. 6) was observed on the single crosses and the smallest (13. 5) to the open pollinated progenies. There was also a reduction in the number of culms between

Table 18. Analysis of variance for disease rating in tall fescue.

Source of Variation	SS	d. f.	MS	F
Replications	0.90	4	0.2250	2.98*
Entries	19.40	61	0.3180	4.22**
Among groups	1.77	5	0.3540	1.12
Within groups[1]	17.63	56	0.3148	4.17**
Checks	0.06	1	0.0600	0.79
Single crosses	8.05	27	0.2981	3.95**
Polycrosses	1.45	7	0.2071	2.75**
Selfed	1.64	7	0.2343	3.11**
Open pollinated	1.03	7	0.1471	1.95
Parents	5.40	7	0.7714	10.23**
Error	18.41	244	0.0754	---
Total	38.71	309	---	---

[1] Used as error term for calculating F for among groups

* Significant at the 5% level ** Significant at the 1% level

Table 19. Mean disease rating[1] values for checks and different methods of progeny testing[1] in tall fescue, as recorded on June 14, 1962.

Entries	Disease Incidence
Checks	1.46
Sx	1.76
Px	1.70
S_1	1.66
OP	1.60
Parents	1.76

[1] 0, no lessions; 1, 0-5% leaf spots; 2, 6-25% leaf spots; 3, 26-50% leaf spots; 4, 51-100% leaf spots; 5, dead.

Table 20. Average disease rating[1] per plant of tall fescue progenies,[2] as recorded on June 14, 1962.

Parent Identification	Progeny Testing Method[2,3] Px	S_1	OP	Parents
304	1.8	1.9	1.9	1.7
314	1.8	1.9	1.6	2.0
315	2.0	1.8	1.7	2.2
339	1.5	1.6	1.6	2.2
340	1.8	1.5	1.6	1.8
342	1.5	1.5	1.5	1.2
351	1.4	1.3	1.4	1.8
352	1.9	1.8	1.5	1.2

[1] 0, no lessions; 1, 0-5% leaf spots; 2, 6-25% leaf spots; 3, 26-50% leaf spots; 4, 51-100% leaf spots; 5, dead.

[2] Px = polycross S_1 = selfed OP = open pollinated

[3] Average disease rating for checks: Alta = 1.4
Kentucky 31 = 1.5

Table 21. Analysis of variance for number of culms per plant in tall fescue.

Source of Variation	SS	d. f.	MS	F
Replications	1932.29	4	483.0725	32.11**
Entries	10358.97	61	169.8192	11.29**
Among groups	6122.58	5	1224.5200	16.18**
Within groups[1]	4236.39	56	75.6500	5.03**
Checks	51.076	1	51.0760	3.39
Single crosses	1917.15	27	71.0055	4.72**
Polycrosses	369.39	7	52.7700	3.51**
Selfed	1115.83	7	159.4043	10.60**
Open pollinated	309.02	7	44.1457	2.93**
Parents	473.91	7	67.7014	4.50**
Error	3670.65	244	15.0436	---
Total	15961.91	309	----	---

[1] Used as error term to calculate F for among groups

** Significant at the 1% level

the parents (23.9) and the S_1's (14.7) due to inbreeding depression (Table 22).

The number of culms for the single crosses ranged from 16.3 to 30.6 (Table 24); for the polycrosses, from 17.2 to 28.0; for the S_1, from 9.6 to 23.8; for the OP, from 9.0 to 18.5; and for the parents, from 16.9 to 26.4. The largest range of variation corresponded to the single crosses and the S_1's and the lowest to the parents and open pollinated progenies (Table 23).

There was a significant negative correlation for number of culms per plant between single crosses and the mean of the parents (r = -0.63**) and between single crosses and the mean of the smallest parent (r = -0.66**). For the same character, the association was also negative (-0.80*) between the parents and S_1's (Table 25).

The combining ability analyses (Table 26) gave significance at the one percent level for general combining ability but not for specific combining ability. Culms per plant, therefore, seem to respond primarily to the effects of general combining ability. Parent 342 had the highest combining ability effect and parent 315 the lowest (Table 27).

Seed Yield

Neither the differences between checks nor the differences between polycrosses were significant. However, the differences

Table 22. Mean number of culms per plant for checks and different methods of progeny testing[1] in tall fescue, as recorded on June 14-22, 1962.

Entries	Number of Culms
Checks	17.90
Sx	24.60
Px	21.55
S_1	14.66
OP	13.48
Parents	23.89

[1] Sx = single cross Px = polycrosses S_1 = selfed OP = open pollination

Table 23. Average number of culms per plant of tall fescue progenies, as recorded on June 14-22, 1962.

Parent Identification	Progeny Testing Methods Px	S_1	OP	Parents
304	20.6	9.6	15.1	24.2
314	28.0	15.7	14.8	23.9
315	21.9	7.9	14.1	25.1
339	22.6	19.1	18.5	24.2
340	18.9	11.5	10.9	26.4
342	23.1	23.8	11.3	16.9
351	17.2	10.4	9.0	29.3
352	20.1	19.1	14.1	21.1

Table 24. Average number of culms per plant in tall fescue single crosses, as recorded on June 14-22, 1962.

Parents	304	314	315	339	340	342	351	352	Total
304	---	16.98	19.56	22.80	21.98	24.48	16.26	23.72	145.78
314		---	20.66	23.86	24.82	27.72	21.96	24.40	160.40
315			---	27.52	26.24	32.48	22.48	26.66	175.60
339				---	26.02	30.56	22.22	28.12	181.10
340					---	27.90	22.78	28.00	177.74
342						---	28.14	27.52	198.80
351							---	23.12	156.96
352								---	181.54

Table 25. Simple correlation coefficients (r) between different progeny testing methods for culms per plant in tall fescue.

	r	n[1]
Single crosses vs. mean of parents	-0.63**	28
Single crosses vs. largest parent	-0.30	28
Single crosses vs. smallest parent	-0.65**	28
Polycross vs. selfed	0.37	8
Polycross vs. OP	0.51	8
Polycross vs. parents	0.44	8
Selfed vs. OP	0.17	8
Selfed vs. parents	-0.80*	8
Parents vs. OP	-0.19	8

[1] n = number of paired observations

* Significant at the 5% level ** Significant at the 1% level

Table 26. General (GCA) and specific (SCA) combining ability analysis for culms per plant in tall fescue single crosses.

Source of Variation	SS	d.f.	MS	F
Replications	1403.08	4	350.77	22.45**
Single crosses	1917.15	27	71.00	4.54**
GCA	1654.80	7	236.40	15.13**
SCA	262.35	20	13.12	0.84
Error	1686.91	108	15.62	---
Total	5007.14	139	---	---

** Significant at the 1% level

Table 27. Estimates for general combining ability effects and variances for number of culms in tall fescue single crosses.

Parent Identification	General Combining Ability	
	Effects	Variances
304	-4.4100	18.9925
314	-1.9733	3.4383
315	0.5600	-0.1420
339	1.4767	1.7250
340	0.9167	3.8472
342	4.4267	19.1401
351	-2.5467	6.0301
352	1.5500	1.9469

between entries and within each one of the other progeny testing methods except polycross were significant at the one percent level (Table 28).

The largest mean seed yield per plant corresponded to the single crosses (21.41 gr.) and the lowest to the S_1's (7.87 gr.) which showed a marked inbreeding depression in relation to the parents (Table 29).

The variation in seed yield ranged from 7.74 to 33.46 gr. for single crosses (Table 31); from 15.20 to 23.18 gr. for polycross progenies; from 1.7 to 22.52 gr. in S_1's; from 4.68 to 22.78 gr. in open pollinated progenies; and from 8.32 to 35.46 gr. in the

Table 28. Analysis of variance for open pollinated seed yield in tall fescue as harvested from rows under natural conditions.

Source of Variation	SS	d. f.			MS	F
Replications	1761.6595	4			440.4149	10.00**
Entries	20602.5567	61			337.7468	7.67**
Among groups	8123.2894		5		1624.6579	7.29**
Within groups[1]	12479.2673		56		222.8440	5.06**
Checks	18.7690			1	18.7690	0.43
Single crosses	5808.4465			27	215.1276	4.88**
Polycrosses	249.7360			7	35.6766	0.81
Selfed	1976.0110			7	282.2873	6.41**
Open pollinated	1387.4150			7	198.2021	4.50**
Parents	3038.8898			7	434.1271	9.85**
Error	10659.4325	242			44.0472	---
Total	33023.5487	307			----	---

[1] Used as error term to calculate F for among groups

** Significant at 1% level

Table 29. Mean open pollinated seed in grams,[1] as recorded for checks and different progeny testing methods in tall fescue on July 1-3, 1962.

Entries	OP seed gr.
Checks	9.33
Sx	21.41
Px	19.69
S_1	7.87
OP	11.81
Parents	17.74

[1] Sx = single crosses Px = polycrosses S_1 = selfed
OP = open pollination

parents. The largest range of variation in seed yield corresponded to the parents and the smallest to the polycross progenies (Table 30).

S_1 and open pollinated progenies (r = 0.71**) were positively associated for seed yield as shown on Table 32.

Seed yield responded to the effects of both general (F = 18.84**) and specific (F = 2.34*) combining ability. Nevertheless, the variance for general combining ability was larger than the variance for specific combining ability, which indicates that the additive effects are more evident than the nonadditive (Table 33).

Table 30. Mean open pollinated seed yield in grams per plant harvested on row basis, as recorded on July 1-3, 1962, in tall fescue progenies.[1,2]

Parent Identification	Progeny Testing Methods: Px	S_1	OP	Parents
304	20.00	2.90	11.30	22.92
314	21.36	1.70	6.14	10.48
315	17.10	0.86	9.88	14.30
339	23.18	7.32	19.36	23.00
340	19.32	7.78	8.20	22.27[3]
342	22.40	22.52	22.78	9.36
351	15.20	4.50	4.68	35.46
352	18.96	15.42	12.18	8.32

[1] Px = polycross S_1 = selfed OP = open pollinated

[2] Mean yield for checks: Alta = 10.70 gr.
Kentucky 31 = 7.96 gr.

[3] Average of four replications

Table 31. Mean open pollinated seed yield of tall fescue single crosses, as recorded on July 1-3, 1962.

Parents	304	314	315	339	340	342	351	352	Total
304	---	7.74	9.76	20.26	17.82	24.88	15.18	23.76	119.40
314		---	7.92	17.10	18.20	25.80	14.74	19.92	111.42
315			---	24.66	27.26	33.46	22.54	26.08	151.68
339				---	22.74	32.04	17.94	26.66	161.40
340					---	20.86	20.28	23.60	150.76
342						---	28.62	29.40	195.06
351							---	22.92	142.22
352								---	172.34

Table 32. Simple correlation coefficients (r) between different methods of progeny testing for open pollinated seed yield in tall fescue.

	r	n[1]
Single crosses vs. mean of parents	-0.26	28
Single crosses vs. largest parent	-0.19	28
Single crosses vs. smallest parent	-0.28	28
Polycross vs. selfed	0.38	8
Polycross vs. OP	0.72	8
Polycross vs. parents	-0.46	8
Selfed vs. OP	0.71*	8
Selfed vs. parents	-0.44	8
OP vs. parents	-0.37	8

[1] n = number of paired observations

* Significant at the 5% level

Table 33. General (GCA) and specific (SCA) combining ability analysis for open pollinated seed yield in tall fescue single crosses.

Source of Variation	SS	d. f.		MS	F
Replications	1323.17	4		330.79	10.17**
Single crosses	5808.45	27		215.13	6.62**
GCA	4288.21		7	612.60	18.84**
SCA	1520.24		20	76.01	2.34*
Error	3478.31	107		32.51	---
Total	10609.93	138		----	---

* Significant at the 5% level ** Significant at the 1% level

The best combiner was parent 314 and the worst parent 340, according to the information presented on Table 34.

Table 34. Estimates of general combining ability effects and variances for seed yield in tall fescue single crosses.

Parent Identification	General Combining Ability	
	Effects	Variances
304	-5.1982	23.3817
314	-6.5192	38.9539
315	0.1908	-3.5097
339	1.8108	-0.0267
340	0.0375	-3.5447
342	7.4208	19.6075
351	-1.3858	-1.6257
352	3.6342	9.6620

Self-Seed

According to the information presented on Table 35, there were significant differences in self-seed yield for entries, single crosses and S_1's. No significance was found between progeny testing methods, checks, polycrosses, open pollination or parents.

Single crosses ranged from 0.0237 to 0.4484 gr. (Table 38) and S_1's from 0.0063 to 0.4840 gr. (Table 37).

Self-seed yield for single crosses was associated with the mean self-seed yield of the parents (r = 0.84**), but not with the

Table 35. Analysis of variance for self-seed in tall fescue, as harvested from three enclosed panicles.

Source of Variation	SS	d.f.	MS	F
Replications	0.01042965	4	0.00260741	0.15
Entries	3.63231976	61	0.05954622	3.37**
Among groups	0.35365086	5	0.07073017	1.21
Within groups[1]	3.27866890	56	0.05854766	3.31**
Checks	0.01627061	1	0.01627061	0.92
Single crosses	1.90539162	27	0.07057006	3.99**
Polycrosses	0.12532059	7	0.01790294	1.01
Selfed	0.90838257	7	0.12976894	7.24**
Open pollinated	0.20962242	7	0.02994606	1.69
Parents	0.11368109	7	0.01624015	0.92
Error	4.31402024	244	0.01768041	---
Total	7.34634000	309	----	---

[1] Used as error term to calculate F for among groups

** Significant at the 1% level

Table 36. Mean self-seed in grams for checks and different progeny testing methods[1] in tall fescue, as recorded on July 5-7, 1962, from three enclosed panicles.

Entries	Self-Seed gr.
Checks	0.1072
Sx	0.1938
Px	0.1613
S_1	0.1359
OP	0.1615
Parents	0.0996

[1] Sx = single crosses Px = polycrosses S_1 = selfed
OP = open pollination

one of either the largest or the smallest parent (Table 39). There was a correlation for self-seed yield (r = 0.72*) between polycross and open pollinated progenies.

The combining ability analysis is shown on Table 40, and it points out significant differences for general combining ability. This indicates that self-seed responds primarily to the effects of general combining ability.

As shown on Table 41, parent 351 had the largest combining ability, whereas the smallest was observed on parent 304.

Table 37. Mean self pollinated seed yield in grams of tall fescue progenies,[1] as recorded on July 5-7, 1962, from three enclosed panicles.

Parent Identification	Progeny Testing Methods Px	S_1	OP	Parents
304	0.1747	0.0188	0.0862	0.1401
314	0.1140	0.0325	0.1186	0.0338
315	0.1202	0.0063	0.1014	0.0658
339	0.1360	0.1044	0.1606	0.1651
340	0.1079	0.0510	0.0886	0.0594
342	0.2859	0.2405	0.2875	0.0399
351	0.1487	0.4840	0.2534	0.1163
352	0.2035	0.1500	0.1957	0.1763

[1] Px = polycrosses S_1 = selfed OP = open pollination

[2] Mean self pollinated seed yield for checks: Alta = 0.0673 gr.
Kentucky 31 = 0.1474 gr.

Table 38. Mean self-seed yield in grams of tall fescue single crosses, as collected from three enclosed panicles on July 5-7, 1962.

Parents	304	314	315	339	340	342	351	352	Total
304	---	0.0237	0.0300	0.2742	0.1164	0.2227	0.2983	0.1092	1.0745
314		---	0.0495	0.1353	0.0450	0.2226	0.4158	0.1287	1.0206
315			---	0.1236	0.1438	0.3753	0.3443	0.1447	1.2112
339				---	0.1172	0.3545	0.2129	0.1111	1.3288
340					---	0.1992	0.2172	0.0630	0.9018
342						---	0.4484	0.2404	2.0631
351							---	0.2583	2.1952
352								---	1.0554

Table 39. Simple correlation coefficients (r) between different progeny testing methods for self-seed yield in tall fescue.

	r	n[1]
Single crosses vs. mean of the parents	0.84**	28
Single crosses vs. largest parent	-0.03	28
Single crosses vs. smallest parent	0.03	28
Polycross vs. selfed	0.34	8
Polycross vs. OP	0.72*	8
Polycross vs. parents	0.05	8
Selfed vs. OP	0.12	8
Selfed vs. parents	0.13	8
OP vs. parents	0.04	8

[1] n = number of paired observations

*Significant at the 5% level ** Significant at the 1% level

Table 40. General (GCA) and specific (SCA) combining ability analysis for self-seed yield in tall fescue single crosses.

Source of Variation	SS	d.f.		MS	F
Replications	0.01088795	4		0.00272198	0.14
Single crosses	1.90539162	27		0.07057006	3.55**
GCA	1.42862000		7	0.20408800	10.26**
SCA	0.47655500		20	0.02382800	1.20
Error	2.14810531	108		0.01988986	---
Total	4.06438488	139		----	---

** Significant at the 1% level

Table 41. Estimates of general combining ability effects and variances for self-seed yield in tall fescue single crosses.

Parent Identification	General Combining Ability Effects	General Combining Ability Variances
304	-0.0470	0.0016
314	-0.0559	0.0025
315	-0.0242	0.0052
339	-0.0046	0.0004
340	-0.0757	0.0051
342	0.1178	0.0133
351	0.1398	0.0189
352	-0.0501	0.0019

Seed from Three Enclosed Open Pollinated Panicles

The results of the analysis of variance of this experiment are in fairly close agreement with the data reported for seed yield. As in the other experiment, the differences between polycrosses were not significant. The differences were, however, significant for entries, progeny testing methods, checks, single crosses, S_1's, open pollination and parents (Table 42).

The largest mean seed production (3.5828 gr.) corresponded to the polycrosses and the lowest to the S_1 (1.7224 gr.), which showed a marked inbreeding depression in relation to the parents (3.1279 gr.) as shown on Table 43.

Table 43. Mean open pollinated seed yield in grams for checks and different progeny testing methods[1] in tall fescue, as recorded on July 5-7, 1962, from three enclosed panicles.

Entries	Seed Yield gr.
Checks	2.7112
Sx	3.2758
Px	3.5828
S_1	1.7224
OP	2.9312
Parents	3.1279

[1] Sx = single crosses Px = polycrosses S_1 = selfed
OP = open pollination

The range of variation was from 1.7580 to 3.9505 gr. for single crosses (Table 45); from 2.7430 to 3.9922 gr. for polycrosses; from 0.6528 to 3.3950 gr. for S_1; from 2.0796 to 3.5209 gr. for OP; and from 1.7436 to 4.9143 gr. for parents. The largest range of variation for open pollinated seed corresponded to the parents and the lowest to the polycrosses (Table 44).

As illustrated on Table 46, the open pollinated seed yield of the single crosses was positively correlated with the one of the smallest parent (r = 0.50**). The S_1 was associated with the open pollinated progenies (r = 0.76*).

As shown in Table 47, there were significant differences for

Table 44. Mean open pollinated seed yield in grams of tall fescue progenies, as recorded on July 5-7, 1962, from three enclosed panicles.

Parent Identification	Progeny Testing Methods[1]			
	Px	S_1	OP	Parents
304	3.7896	1.3929	2.4327	4.1588
314	2.7465	0.9498	2.0796	1.7436
315	3.3456	0.6528	2.4552	2.6304
339	3.9610	1.4546	2.9187	3.6412
340	3.6391	1.4354	3.3902	3.1832
342	3.9922	3.3950	3.5209	2.4687
351	3.5233	1.9786	3.3949	4.9143
352	3.6650	2.5201	3.2573	2.6314

[1] Px = polycrosses S_1 = selfed OP = open pollinated

[2] Mean open pollinated seed yield for checks: Alta = 2.1588 gr.
Kentucky 31 = 3.4065 gr.

Table 45. Mean open pollinated seed yield in grams of tall fescue single crosses, as recorded on July 5-7, 1962, from three enclosed panicles.

Parents	304	314	315	339	340	342	351	352	Total
304	---	1.9010	1.8426	3.6073	3.2623	3.9040	3.7397	3.5162	21.7731
314		---	1.7580	2.4901	2.4613	3.1310	2.8816	3.1331	17.7561
315			---	3.6028	3.8700	3.5444	3.6944	3.6774	21.9896
339				---	3.1293	3.7828	3.5797	2.9408	23.1328
340					---	3.7669	3.6054	3.1503	23.2455
342						---	3.8921	3.9078	25.9290
351							---	3.9505	25.3434
352								---	24.2761

Table 46. Simple correlation coefficients (r) between different progeny testing methods for open pollinated seed yield in tall fescue from three enclosed panicles.

	r	n[1]
Single crosses vs. mean of parents	0.37	28
Single crosses vs. largest parent	0.17	28
Single crosses vs. smallest parent	0.50**	28
Polycross vs. selfed	0.58	8
Polycross vs. OP	0.64	8
Polycross vs. parents	0.44	8
Selfed vs. OP	0.76*	8
Selfed vs. parents	0.01	8
OP vs. parents	0.31	8

[1] n = number of paired observations

* Significant at the 5% level ** Significant at the 1% level

Table 47. General (GCA) and specific (SCA) combining ability analysis for open pollinated seed yield collected from three enclosed panicles in tall fescue single crosses.

Source of Variation	SS	d.f.	MS	F
Replications	0.706047	4	0.17651175	0.40
Single crosses	57.27441	27	2.121275	4.87**
GCA	38.13596	7	5.44799	12.50**
SCA	19.13804	20	0.95690	2.19**
Error	47.0671685	108	0.43580711	---
Total	105.04762554	139	----	

** Significant at the 1% level

both general and specific combining ability.

The best combiner was parent 314 and the poorest were 315 and 339, according to the information presented on Table 48.

Self-Fertility Percentage

Self-fertility, as measured by the formula

$$\frac{\text{weight of seeds set per panicle under bag}}{\text{weight of seeds set per panicle in the open}} \times 100$$

ranged from 3.2 percent in the parents to 8.0 percent in the S_1's; thus, indicating an increase in self fertility as a consequence of inbreeding (Table 49). These results do not coincide with what has been reported in the literature (Cowan 12, p. 72).

Panicles not Harvested

After the seeds were harvested by hand, a visual rating was made to evaluate the extent of the panicles not harvested. This was done because at harvest time some of the panicles were too immature. The analysis for the results of the evaluation of this rating is shown in Table 50, and the means for the checks and methods of progeny testing in Table 51. Except for the checks, it appears that there were significant differences between and within progeny testing methods.

Table 48. Estimates of general combining ability effects and variances of open pollinated seed of tall fescue single crosses.

Parent Identification	General Combining Ability Effects	General Combining Ability Variances
304	-0.1929	0.0270
314	-0.8624	0.7310
315	-0.1568	0.0119
339	0.0337	0.0116
340	0.0525	-0.0100
342	0.4997	0.2370
351	0.4021	0.1490
352	0.2242	0.0376

Table 49. Percentage of self-fertility for checks and different methods of progeny testing[1] for tall fescue.

Entries	%
Checks	4.0
Sx	6.0
Px	4.5
S_1	8.0
OP	5.5
Parents	3.2

[1] Sx = single crosses Px = polycrosses S_1 = selfed
OP = open pollination

Table 50. Analysis of variance for the extent of the panicles not harvested in tall fescue.

Source of Variation	SS	d. f.	MS	F
Replications	9.25	4	2.31	5.13**
Entries	215.28	61	3.53	7.84**
Among groups	34.67	5	6.93	1.55
Within groups[1]	249.95	56	4.46	9.91**
Checks	00.00	1	0.00	0.00
Single crosses	59.94	27	2.22	4.93**
Polycrosses	8.00	7	1.14	2.53*
Selfed	39.17	7	5.60	12.44**
Open pollinated	16.17	7	2.31	5.13**
Parents	57.50	7	8.21	18.24**
Error	108.75	244	0.45	---
Total	333.28	309	---	---

[1] Used as error term to calculate F for among groups

* Significant at the 5% level ** Significant at the 1% level

As shown in Table 51 and 52, the mean rating for parents, S_1 and OP was very close (around 3. 3). Single crosses and poly-crosses also had the same mean (4. 0).

Forage

Forage yield after seed harvesting was taken as a measure of recovery. The information on the character is presented in Tables 53 through 58.

As shown in Table 53, the differences for entries, among groups, for single crosses, and for parents were all significant at the one percent level. No significant differences were found for checks. polycrosses, S_1 or open pollinated progenies.

The forage yield for the progeny testing methods ranged from 27. 63 gr. for the S_1's to 40. 83 gr. for the single crosses. There was also an inbreeding depression for these characters, since the mean of the parents (32. 79 gr.) exceeded the mean of the S_1's (27. 63 gr. Table 54).

The single crosses ranged from 30. 30 to 55. 44 gr. (Table 56) and the parents from 18. 54 to 43. 10 gr., as shown in Table 55. The range of variation for forage yield was slightly larger for the single crosses.

The F_1 forage yield was positively correlated with the forage

Table 51. Mean rating[1] on the extent of the panicles not harvested for checks and progeny testing methods[2] in tall fescue, as recorded on July 10, 1962.

Entries	Rating
Checks	3.8
Sx	4.0
Px	4.0
S_1	3.3
OP	3.4
Parents	3.3

[1] 1, plants practically unharvested, to 5, completely harvested

[2] Sx = single crosses Px = polycrosses S_1 = selfed
OP = open pollination

Table 52. Rating[1] on the extent of panicles not harvested of tall fescue progenies, as recorded on July 10, 1962.

Parent Identification	Progeny Testing Methods[2] Px	S_1	OP	Parents
304	4.4	3.8	4.0	4.6
314	4.0	2.2	2.6	2.0
315	3.4	1.4	2.4	2.0
339	3.4	3.4	3.8	3.2
340	4.6	3.8	3.4	5.0
342	4.2	4.2	4.0	4.0
351	3.6	3.2	2.8	4.2
352	4.4	4.6	4.0	1.8

[1] 1 = plants practically unharvested to 5 = plants completely harvested

[2] Px = polycross S_1 = selfed OP = open pollination

[3] Mean rating for checks: Alta = 3.8
Kentucky 31 = 3.8

Table 53. Analysis of variance for forage yield in tall fescue.

Source of Variation	SS	d. f.	MS	F
Replications	2632.58	4	658.1450	6.27**
Entries	21127.64	61	346.3547	3.30**
Among groups	6795.38	5	1359.0760	5.31**
Within groups[1]	14332.26	56	255.9330	2.44**
Checks	65.03	1	65.0300	0.62
Single crosses	8944.37	27	331.2729	3.16**
Polycrosses	846.32	7	120.9000	1.15
Selfed	835.24	7	119.3200	1.14
Open pollinated	934.18	7	133.4500	1.27
Parents	2707.02	7	386.7171	3.68**
Error	25605.73	244	104.9415	---
Total	49365.95	309	----	---

[1] Used as error term to calculate F for among groups

** Significant at the 1% level

Table 54. Forage yield mean values for different methods of progeny testing[1] in tall fescue expressed as weight in grams (gr.) on single plant basis.

Entries	Forage Yield gr.
Checks	30.45
Sx	40.83
Px	36.95
S_1	27.63
OP	34.83
Parents	32.79

[1] Sx = single crosses   Px = polycrosses S_1 = selfed
OP = open pollination

Table 55. Mean weight in grams of forage per plant for checks and different progeny testing methods of tall fescue progenies, as recorded on September 8-10, 1962.

Parent Identification	Progeny Testing Methods[1] Px	S_1	OP	Parents
304	32.36	21.10	32.50	27.80
314	35.62	25.70	40.12	41.64
315	42.74	21.82	34.88	34.06
339	36.44	30.12	37.50	43.10
340	32.84	25.38	40.00	35.92
342	31.08	34.76	26.72	18.54
351	40.78	31.66	38.50	38.02
352	43.78	30.56	28.48	23.30

[1] Px = polycrosses S_1 = selfed OP = open pollinated

Table 56. Average dry weight in grams on single plant basis for tall fescue single crosses, as recorded on September 8-10, 1962.

Parents	304	314	315	339	340	342	351	352
304	---	29.02	35.54	46.22	51.70	24.72	34.80	31.14
314		---	36.08	52.32	48.50	33.50	50.16	40.38
315			---	47.46	41.14	38.58	55.44	48.12
339				---	54.32	36.46	40.34	42.88
340					---	32.98	46.68	33.26
342						---	30.30	32.00
351							---	39.10
352								---

yield of the mean of the parents (r = 0.72**), the largest parent (r = 0.51**) and the smallest parent (r = 0.71**). The performance of the parental forage yield was positively correlated (r = 0.74*) with the one of the open pollinated progenies (Table 57).

Forage yield seems to respond mainly to additive gene action, as evidenced by the combining ability analysis (Table 58).

According to the information presented on Table 59, the best general combining ability was shown by parent 342 and the poorest by parent 351.

Association Between Characters for Single Crosses

Correlation coefficients were calculated for the characters measured in the experiment with the exception of disease incidence and the number of panicles not harvested. Data from single crosses were used to calculate the associations between characters and the results are shown in Table 60. Self-seed was positively correlated with open pollinated seed from both rows (r = 0.46*) and three enclosed panicles (r = 0.61**). Open pollinated seed from rows was associated (r = 0.74**) with open pollinated seed from three enclosed panicles. These last three associations suggest that either one of the three methods may lead to comparable results in estimating seed yield. Culms per plant were positively correlated with

Table 57. Simple correlation coefficients (r) between different methods of progeny testing for forage yield in tall fescue.

	r	n[1]
Single crosses vs. mean of the parents	0.72**	28
Single crosses vs. largest parent	0.51**	28
Single crosses vs. smallest parent	0.71**	28
Polycrosses vs. selfed	0.00	8
Polycrosses vs. OP	-0.02	8
Polycrosses vs. parents	0.10	8
Selfed vs. OP	-0.35	8
Selfed vs. parents	0.03	8
OP vs. parents	0.74*	8

[1] n = number of paired observations

* Significant at the 5% level ** Significant at the 1% level

Table 58. General (GCA) and specific (SCA) combining ability analysis for forage yield in tall fescue single crosses.

Source of Variation	SS	d.f.		MS	F
Replications	989.94	4		247.48	2.03
Single crosses[1]	8944.37	27		331.27	2.72**
GCA	5362.41		7	766.05	6.30**
SCA	3581.95		20	179.10	1.47
Error	13130.86	108		121.58	---
Total	23065.17	139		----	---

** Significant at the 1% level

Table 59. Estimates of general combining ability effects and variances for forage yield in tall fescue single crosses.

Parent Identification	General Combining Ability	
	Effects	Variances
304	-3.7742	10.6985
314	2.3625	2.0353
315	2.7625	4.0853
339	5.7025	28.9664
340	3.7992	10.8878
342	-9.5408	87.4808
351	1.8392	0.1635
352	-3.1508	6.3814

open pollinated seed from both rows (r = 0.87**) and enclosed panicles (r = 0.43*). According to these correlations, number of culms per plant may be taken as an indication of potential seed yield. Height was correlated with maturity (r = 0.87**) and culms per plant (r = 0.44*).

Heritability Estimates

Both broad- and narrow-sense heritability estimates were calculated on the basis of the combining ability analysis and the results are shown in Table 61. With the exception of maturity and number of culms per plant, broad-sense heritability estimates were

Table 60. Simple correlation coefficients (r) between characters for tall fescue single crosses.

Characters	Height	Maturity	Culms/ plant	OP[1] seed	Self-seed	OP[2] seed	Forage
Height	---	0.88**	0.44*	0.28	0.28	0.13	0.03
Maturity		---	0.29	0.08	0.09	-0.04	0.23
Culms/plant			---	0.87**	0.26	0.43*	-0.13
OP[1] seed				---	0.47*	0.74**	-0.17
Self-seed					---	0.61**	-0.07
OP[2] seed						---	-0.11
Forage							---

[1] Open pollinated seed harvested on row basis

[2] Open pollinated seed harvested from three enclosed panicles

* Significant at the 5% level

** Significant at the 1% level

equal to or larger than narrow-sense heritability estimates. The lowest estimates of heritability corresponded to forage yield. Height gave the largest broad-sense heritability (52.51 percent), whereas the largest narrow-sense heritability (49.33 percent) was observed in the number of culms per plant.

Table 61. Heritability estimates for different measurable characters in tall fescue, calculated on the basis of components of variance from combining ability analysis.

Characters	Broad-Sense Heritability Estimate	Narrow-Sense Heritability Estimate
	%	%
Height	52.51	47.46
Maturity	47.64	47.64
Number of culms per plant	49.33	49.33
Seed yield[1]	59.31	48.42
Self-seed yield	39.65	37.26
Open pollinated seed[2]	50.14	38.22
Forage	30.94	24.40

[1] Seed yield harvested under ordinary conditions

[2] Open pollinated seed from three enclosed panicles

Comparison of Progeny Testing Methods

For each character within each progeny testing method, the means were ranked from the largest to the smallest. The purpose of this arrangement was to see how one method compares with another in estimating combining ability. The results appear on Tables 62 through 67.

In the case of polycross progeny testing (Table 62), the ranking for combining ability varied according to the character measured. On the average, progeny from parent 342 ranked first, whereas the last place was observed in the case of the progenies from parents 315 and 351.

The ranking for combining ability also changed from characteristic to characteristic in the case of single crosses (Table 63). The best average rating was observed on the progeny from parent 342 and the poorest on the progeny from parent 315.

The ranking for open pollination is illustrated in Table 64 and here, again, there is no agreement from characteristic to characteristic in the ranking for combining ability. The results are in agreement with what was found in the case of polycrosses: progeny from parent 342 ranked first and progeny from parent 315 ranked last.

Table 65 was made by considering seven out of the nine

Table 62. Comparison of the general combining ability of nine characteristics of tall fescue as evaluated by polycross progeny testing.

Parent Identification	Height	Maturity	Disease Incidence	Culms per Plant	OP[1] Seed	Self-Seed	Panicles not Harvested	OP[2] Seed	Forage	Average Ranking
304	2	3	3	5	4	3	2	2	5	2
314	1	3	3	1	3	5	4	6	4	2
315	4	4	5	4	6	5	6	5	2	4
339	6	6	2	3	1	4	6	1	4	3
340	1	1	3	6	4	5	1	3	5	2
342	2	2	2	2	2	1	3	1	6	1
351	5	5	1	7	7	4	5	4	3	4
352	3	5	4	5	5	2	2	3	1	2

[1] Open pollinated seed harvested on row basis

[2] Open pollinated seed harvested from three enclosed panicles

Table 63. Comparison of the general combining ability of nine characteristics of tall fescue as evaluated by self pollination.

Parent Identification	Height	Maturity	Disease Incidence	Culms per Plant	OP[1] Seed	Self-Seed	Panicles not Harvested	OP[2] Seed	Forage	Average Ranking
304	4	3	5	5	6	5	3	4	5	4
314	1	1	5	3	6	5	5	5	4	5
315	5	6	4	6	7	6	6	6	5	6
339	3	2	3	2	3	4	4	4	3	3
340	2	1	2	4	3	5	3	4	4	3
342	1	1	2	1	1	2	2	1	1	1
351	4	5	1	4	4	1	4	3	2	3
352	3	4	4	2	2	3	1	2	3	2

[1] Open pollinated seed harvested on row basis

[2] Open pollinated seed harvested from three enclosed panicles

Table 64. Comparison of the general combining ability of nine characteristics of tall fescue as evaluated on the basis of open pollination.

Parent Identification	Height	Maturity	Disease Incidence	Culms per Plant	OP[1] Seed	Self-Seed	Panicles not Harvested	OP[2] Seed	Forage	Average Ranking
304	2	1	5	2	3	5	1	5	4	3
314	1	1	3	2	5	4	5	6	1	3
315	6	3	4	2	4	4	6	5	3	5
339	4	4	3	1	2	3	2	4	2	2
340	3	1	3	4	4	5	3	2	1	2
342	5	2	2	3	1	1	1	1	6	1
351	6	5	1	5	6	1	4	2	2	4
352	6	2	2	2	3	2	1	3	5	2

[1] Open pollinated seed harvested on row basis

[2] Open pollinated seed harvested from three enclosed panicles

Table 65. Comparison of the general combining ability of seven characteristics of tall fescue as evaluated on the basis of combining ability analysis.

Parent Identification	Height	Maturity	Culms per Plant	OP[1] Seed	Self-Seed	OP[2] Seed	Forage	Average Ranking
304	2	3	1	2	5	5	3	2
314	5	6	3	1	4	1	6	4
315	7	6	5	5	3	6	5	7
339	4	7	4	5	6	6	2	6
340	1	1	3	5	3	7	3	3
342	2	4	1	3	2	2	1	1
351	6	5	2	5	1	3	7	5
352	3	2	4	4	5	4	4	4

[1] Open pollinated seed harvested on row basis

[2] Open pollinated seed harvested from three enclosed panicles

characteristics measured in the experiment, since there was no combining ability analysis made for disease incidence and panicles not harvested. As in the last three tables, there was no one-to-one agreement from characteristic to characteristic. On the average, the first ranking corresponded to the progeny from parent 342 and the last to the progeny from parent 315.

In table 66 is shown how the original eight parents were rated within each one of the measured characteristics. As in the case of their progenies, the parents ranked differently from characteristic to characteristic. The first place across characteristics was observed on parent 351, and the last place on parent 342.

For the same reason given for Table 65, disease incidence and panicles not harvested were also discarded in organizing Table 67. The rankings for the other seven characteristics were averaged for each progeny testing method, including combining ability analysis. This last average permitted to group the polycrosses into four categories, the single crosses into six, the open pollinated progenies into five, the combining ability analysis into seven, and the original parental genotypes into five. All methods agreed in selecting the best combiner, parent 342, which happened to be the poorest among the parents. Three of the methods, combining ability analysis, self pollination and open pollination agreed on

Table 66. Comparison of eight early maturing genotypes of tall fescue as evaluated by nine measurable variables.

Parent Identification	Height	Maturity	Disease Incidence	Culms per Plant	OP[1] Seed	Self-Seed	Panicles not Harvested	OP[2] Seed	Forage	Average Ranking
304	2	2	2	4	2	3	2	2	4	2
314	1	1	4	4	4	6	5	6	1	4
315	2	1	5	2	3	5	5	5	3	4
339	3	2	5	4	2	2	4	3	1	3
340	1	1	3	2	2	5	1	4	3	2
342	4	3	1	6	5	6	3	5	6	6
351	2	2	3	1	1	4	3	1	2	1
352	5	3	1	5	5	1	6	5	5	5

[1] Open pollinated seed harvested on row basis

[2] Open pollinated seed harvested from three enclosed panicles

Table 67. Comparison[1] of four progeny testing methods and the original eight parental genotypes as to the ability to evaluate general combining ability on an average of seven characteristics.

Parent Identification	Polycross	Self Pollination	Open[2] Pollination	Combining Ability Analysis	Parental Genotypes
304	2	5	3	2	2
314	2	4	2	4	3
315	3	6	5	7	3
339	2	3	2	6	2
340	2	3	2	3	2
342	1	1	1	1	5
351	4	3	5	5	1
352	2	2	4	4	4

[1] The figures in this table were calculated on the basis of the average of the figures contained in Tables 62 to 66.

[2] Open pollinated seed harvested on row basis.

selecting the poorest combiner, parent 315. For the rest of the parents, however, the agreement between the methods was not that close.

DISCUSSION

Apparently, the height of the F_1 plants was positively associated with both the mean height of the parents and that of the largest parent. Height was also associated with the number of culms per plant and the stage of maturity before harvesting. If these correlation coefficients are taken as an indication of pleiotrophy, selection for height may, at the same time, mean selection for earlier maturing plants.

Maturity, as in height, was positively associated in the F_1 with the maturity of both the mean of the parents and the largest parent. Maturity was, however, independent from the other characters with the exception of height. The positive association between the maturity of the polycrosses and that of the open pollinated progenies suggests the possibility that either one of the two methods may lead to comparable results in evaluating this characteristic.

Helminthosporium dyctioides has been reported as one of the most serious pathogens affecting tall fescue (13, p. 283-320). Luckily, the incidence of this disease did not have a marked effect on the overall performance in the nursery. There were, though, a few plants which were heavily attacked by the organism, but perhaps no more than one or two died from the disease. This probably substantiates what has been already reported about tall fescue being a fairly disease resistant plant.

The number of culms per plant for the F_1 was found to be negatively associated with the number of culms per plant of both the mean of the parents and the smallest parent. The number of culms per plant was also positively associated with seed yield, thus, indicating that this character may be a good indication of the potential seed production ability, although Cowan (13, p. 283-320) states that the amount of seed produced per panicle appears to be a better indication. Therefore, selection for smaller plants might mean a reduction in seed and culm numbers. The negative relationship between parents and inbreds probably indicates that inbreeding also reduces the number of culms per plant.

The act of bagging open pollinated seed did cause differences in seed production, as compared with open pollinated seed produced under natural conditions. For instance, F_1 open pollinated seed was positively correlated with open pollinated seed from the smallest parents in the case of seeds produced under bags; under natural conditions, F_1 open pollinated seed was completely independent from open pollinated seed from either the mean, the largest or the smallest parent. Nevertheless, the association between S_1 and open pollinated seed was significant and positive in both instances. This indicates that either one of the methods may be useful in estimating seed yield. The percentages of self-fertility, calculated in this experiment, substantiate once more the fact that tall fescue is highly self-sterile. Nevertheless, inbreeding increased the percentage of self-fertility. This information refers only to the first generation of inbreeding and, therefore, should not be taken as a generalization for further generations.

The percent of panicles not harvested points out one of the problems of fescue breeding. It deals with the lack of uniformity in seed setting and this was observed again in this experiment.

Forage yield was taken as a measure of recovery after seed harvest, since this characteristic is very important for both forage and seed production. In spite of being so influenced by environment, F_1 forage yield was positively correlated with forage yield from the mean of the parents, the largest and the smallest parent. It was independent from the other characters measured and, therefore, selection for forage yield does not hinder seed production or vice versa. Selection for the other traits would not improve forage yield. Recovery, in general, was good for all plants in the nursery.

The varieties, Alta and Kentucky 31, behaved remarkably similarly, since they differed only in one out of the ten characteristics measured. The only characteristic in which they differed was the amount of open pollinated seed which was collected from panicles enclosed after being cross pollinated. It may be possible that the similarity in the performance of the two varieties is an indication of a common genetic background.

Except for the visual ratings of disease and panicles not harvested (no combining ability analysis was done for them), the characters measured in this experiment responded significantly to general combining ability. This indicates a predominance of additive gene action although the fact that the poorest parent produced the best progenies, regardless the progeny testing method, suggests that nonadditive gene action does play an important role. The disparity between the results of the combining ability analysis and the rest of the data is a probable indication that tall fescue, as a genetic material, does not meet the assumptions underlying the diallel analysis.

Seed yield, as estimated from row basis or from enclosed panicles, responded to both general and specific combining ability, although general combining ability appeared to predominate. This performance indicates good possibilities for using a breeding scheme intended to take advantage of both additive and nonadditive types of gene action. It would be worthwhile trying a reciprocal recurrent selection program for seed yield.

Environment strongly influenced both forage and seed yield, but the environmental influence was more marked in forage than in seed yield. The performance of these two characters is in agreement with what has been reported in the literature, not only for tall fescue but for other grasses as well. For the rest of the characters (excluding disease incidence and panicles not harvested), the environmental influence was not so marked, since both broad- and narrow-sense heritability estimates were above 40 percent.

The fact that broad-sense heritability estimates were larger than narrow-sense heritability estimates, in all but two of the characters measured, also points out that nonadditive gene action might have had an effect on the genetic behavior of the plants in the nursery.

Inbreeding depression, on the basis of the performance of the parents, was evident in height, disease incidence, number of culms per plant, seed and forage yield. Since tall fescue is primarily cross pollinated, this performance was to be expected. No inbreeding depression, however, was observed on the stage of maturity before harvesting, the amount of self-seed, self-sterility and the amount of panicles left unharvested.

The comparison of the progeny testing methods (Tables 62 to 67) showed that there was no complete agreement from one method to another in estimating general combining ability. This might be attributed to the differences in parental genetic diversity between the methods, probably due to different pollen souces. Yet, all the methods were equally effective in selecting the best combiner, parent 342, and, in general, permitted one to roughly separate at least two categories of good and poor combiners. This is especially important in the case of open pollination. If adequately used and if more than four important characteristics are measured, the chances are that the results achieved with this method are going to be effective. Open pollination, thus, would permit an economic and effective early screening of a large number of original genotypes. Genotypes selected on this basis could further be screened with the help of more elaborate techniques, i. e., polycross, self pollination, or, in the case of a reduced number of outstanding selections, a diallel crossing system.

SUMMARY AND CONCLUSIONS

Eight genotypes of tall fescue were selected from a plant population consisting of 9000 individuals. Selection was based on early maturity, self-sterility, seed and forage potential, and nutritive value.

Single crosses, open pollinated, self pollinated and polycross seeds were organized into a randomized block with five replications, each of which contained 63 entries with 10 plants to the entry. The distance between rows was three feet; plants within the entry were planted one foot apart. Alta and Kentucky 31 varieties were used as checks. Parchment bags were used to secure information on self-sterility and seed production. Height, maturity, disease incidence, number of culms per plant, panicles not harvested and forage yield were also evaluated. Griffing's model I, experimental method 4 (26, p. 463-493), was used to test both general and specific combining ability. Simple correlation coefficients were calculated to measure the association between characters and between progeny testing methods within characters.

The height of the F_1 progeny was positively correlated with the height of both the mean of the parents and the largest parent. Height was also correlated with the number of culms per plant and the stage of maturity before harvesting.

The maturity of the F_1 was associated with the maturity of both the mean of the parents and the largest parent. Either poly-cross or open pollination may be used for evaluating maturity with comparable results.

Although there was an incidence of Helminthosporium dyctioides, it was not serious enough to affect markedly the general performance of the plants in the nursery.

The number of culms per plant for single crosses was negatively correlated with the number of culms of both the mean of the parents and the smallest parent. The number of culms per plant was positively correlated with seed yield. Self pollination caused a reduction in the number of culms per plant, from parents to S_1.

F_1 open pollinated seed harvested from enclosed panicles was positively correlated with the smallest parent. Under natural conditions, F_1 open pollinated seed was not correlated with either one of the parent OP seed. In both instances, however, selfing and open pollination were positively associated.

Inbreeding, from parents to S_1, increased the percentage of self fertility.

The evaluation of the number of panicles not harvested revealed that seed setting was not uniform among the plants in the nursery.

F_1 forage yield was correlated with the forage yield of the mean of the parents and both the largest and the smallest parent. Forage yield was independent from the other characters measured.

The checks, Alta and Kentucky 31, behaved remarkably similarly, since they differed only in one out of the nine characteristics measured.

Except for the visual ratings of disease and panicles not harvested, the characters measured in this experiment responded significantly to the effects of general combining ability.

Seed yield, as estimated from either a row basis or an enclosed-panicle basis, responded to both general and specific combining ability.

The comparison of progeny testing methods showed that there was no one-to-one agreement in their ability to determine general combining ability. Yet, all the methods were equally effective in selecting the best combiner, parent 342, and, in general, permitted one to roughly separate at least two categories of good and poor combiners.

Open pollination as a progeny testing method, if properly used, would permit an economic and effective screening of the original parental material on a large number of genotypes.

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