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NOTE
SELECTING PARENTAL MATERIALS FOR HYBRIDIZATION BY DISCRIMINANT FUNCTION[1]

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ABSTRACT

Yield and yield components were measured in thirty cultivars of winter wheat originating from the U.S.A., former U.S.S.R., and the European countries in three years and two locations. Discriminant function was applied to all years and locations to select parents for hybridization aimed at yield improvement. Among all of the functions, only two were significant. The discriminant weights for significant functions, showed that the order of contribution of yield components was kernel per spike, kernel weight, and tiller number. The best two-way and three-way crosses were determined. Genotypes classified as good parents were from different high, medium and low yielding groups.

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گزینش والدین جهت دورگه گیری با استفاده از تابع افتراقی

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به ترتیب دانشجوی سابق دکترا (اکنون استادیار بخش زراعت و اصلاح نباتات دانشکده کشاورزی دانشگاه شیراز، شیراز، ایران) و استادان بخش آگرونومی، دانشگاه ایالتی اکلاهما، استیل‌واتر، اکلاهما ۰۵۰۷-۷٤۰۷۸، آمریکا.

چکیده

عملکرد و اجزاء آن در سی رقم گندم پائیزه آمریکائی، شوروی سابق و اروپایی در سه سال و در دو ایستگاه اندازه گیری گردید. تابع افتراقی برای تمام سالها و ایستگاه‌ها جهت گزینش والدین در دورگه گیری با هدف بهبود محصول بکار برده شد. در بین تمام توابع فقط دو عدد معنی‌دار بود. ضرائب افتراقی برای توابع معنی‌دار نشان داد که میزان اهمیت اجزاء عملکرد در تعیین محصول بترتیب تعداد بذر در خوشه، وزن بذر و تعداد پنجه در واحد سطح بود. بهترین آمیزش‌های دوطرفه و سه‌طرفه تعیین گردید. ژنوتیپ‌هایی که به عنوان والدین خوب طبقه‌بندی شدند از گروه‌های مختلف با محصول زیاد، متوسط و کم بودند.

INTRODUCTION

One of the important aims of plant breeding is to improve yield and quality by developing superior varieties. This is done by altering, to the best advantage, the genetic make-up of the existing cultivars. Choice of parents for hybridization and subsequent selections is very critical. The conventional approaches are restrictive since they necessitate a considerable amount of labor and time. Generally, the breeder makes many crosses, each with a definite purpose, but he has no sure way of knowing their comparative values in advance.

Certain cultivars have a higher value in combining ability than others. The principle of "top crossing" was introduced in 1931 as a valuable technique in maize improvement (8). Jenkins and Brunson (6) concluded that crosses with open-pollinated varieties may be used efficiently in the preliminary testing of new lines. Experimental findings reported in the literature indicate that crosses of unrelated, inbred lines of corn show greater heterosis than do crosses of related lines. The success of many double-cross hybrids over wide areas is the result of their genetic diversity combined with their stability and consistency of performance (1, 9).

In spite of the importance of genetic diversity in hybridization, it is difficult to obtain a dependable estimate of such diversity before making crosses. In the past, ecological and/or geographical diversity has been used as an index of genetic diversity. A number of studies have shown that the divergence between populations could not be related to their geographical distributions (2,3,4). The discriminant function, first developed by Fisher (5, 11), can be used to measure genetic diversity. Discriminant function was applied for varietal selection in tobacco (10) and Smith (12) mentioned it as a tool for selecting parents for hybridization.

MATERIALS AND METHODS

The cultivars used for this study were obtained from wheat architecture nurseries at the Agronomy Research Station, Stillwater, and

Lahoma, Oklahoma. The cultivars originated from the U.S.A., former U.S.S.R., and European countries. The field layout was randomized complete block design as follows:

1. Thirty entries in 1976-77 with three replications at Stillwater.
2. Thirty entries in 1977-78 with four replications at Stillwater and Lahoma.
3. Thirty entries in 1978-79 with four replications each at Stillwater and Lahoma.

Different cultivars were used for each experiment were different in different years. Each entry consisted of four 3-meter rows, with the rows being 30 cm apart. Grain yield and three major components of yield, namely, fertile tiller number per unit area, avarage number of kernels per spike, and average kernel weight were measured.

Analysis Procedures

An analysis of variance was carried out for yield and its components at each location separately. For each location and year, a discriminant analysis was used. The objective of the analysis was to obtain a discriminant function, which is a linear combination of the yield components, to be used for classifying cultivars and their potential crosses into high, medium, or low yield groups. Linear discriminant analysis in this case consists of three populations (or groups) and a set of P variables ($x_1, x_2, \ldots\ldots\ldots x_p$) associated with the individuals in each population. The population discriminant function is a score or index (Z) obtained as a linear combination of the variables. The score on a linear combination of P X's for an individual of group g(g=1,2....G) may be written as:

$$Z_g = a_1 x_{1g} + a_2 x_{2g} + \ldots\ldots + a_p x_{pg}$$

The a values are determined so that they maximize the probability of correctly identifying the group membership of an individual. When a sample of individuals from each population is available, the a's are estimated by maximizing $\lambda = SS_a/SS_w$ were SS_a and SS_w are the sum of squares among and within groups, respectively (11). The maximum values of λ are given by the largest root of $W^{-1}A$ where W and A are the sum of squares and cross products matrices within and among groups, respectively (11).

There is no assurance that the population discriminant function will result in a more correct classification method than simply using a random allocation method. This was investigated using Wilk's likelihood ratio criterion expressed as:

$$\frac{1}{\Lambda} = \frac{|W + A|}{|W|} = |I + W^{-1}A| = (1 + \lambda_1)(1 + \lambda_2) \ldots (1 + \lambda_r)$$

in which r is the number of nonzero characteristic roots of $W^{-1}A$. Barlett (7) showed that:

$$V = [\, n - 1 - (\frac{P + G}{2})\,]\, 1_n \frac{1}{\Lambda}$$

where n, P, and G are the number of observations, variables, and groups, respectively, is distributed approximately as chi-square with p(G-1) degrees of freedom for large n. The sample discriminant function was applied only when it was found to be significant. The significant λ's may be used to compute the characteristic vectors (discriminant weights) by solving the following system of equations:

$$(W^{-1}A - \lambda I)\, a = 0$$

where a is a column vector with three elements (a_1, a_2, a_3) (7).

To employ discriminant analysis, the group of cultivars in each experiment was partitioned into high, medium, and low yield groups based on observed mean yields over replications. Discriminant weights were determined as described above. The resultant discriminant function was represented as:

$$\text{Score} = Z = a_1(\text{tiller number}) + a_2(\text{seeds/spike}) + a_3(\text{kernel weight}).$$

The contribution of each component to Z is represented by the a values.

Subsequent to the determination of the discriminant function, this function was used to predict the scores of all two-way and three-way crosses among the cultivars.

RESULTS AND DISCUSSION

The average yield and yield components for 1978 Stillwater and 1979 Lahoma which had significant λ values are shown in Tables 1 and 2. The analysis of variance corresponding to each character for all experiments (Table 3) shows significant differences among entries for year and location.

The λ and a values for each experiment were estimated and are shown in Table 4. A V statistic corresponding to each λ value was computed, and V's were treated as χ^2 with 6 d.f. The results of this test for all experiments showed that the λ for 1978 Stillwater and 1979 Lahoma are significant (Table 4). The λ value for 1978 Stillwater is 0.8159 while its V value (16.406) is significant at 0.025 level of probability. The score of Z value may be written as:

$$Z=0.0292(\text{tiller number}) + 0.0640(\text{seeds/spike}) + 0.0546(\text{kernel weight}).$$

Table 1. Average yield and yield components for entries grown in 1978, Stillwater.

Parent No.	Entry	Tiller (No./9000 cm^2)	Seeds/ spike	Kernel weight (g/1000 seeds)	Yield* (g/plot)
1	Osage	49	28	30	278.33
2	Tam W-101	47	24	37	311.67
3	Sturdy	37	31	30	273.33
4	Bezostaia 1	29	31	35	230.00
5	Odesskaya	37	32	37	283.33
6	Priboy	40	33	38	293.33
7	Turkey	40	38	29	220.00
8	Scout 66	44	27	33	255.00
9	Triumph 64	44	27	35	283.33
10	Predgornia	29	31	36	231.67
11	Burgas 2	32	39	32	306.67
12	Sadova I	30	32	38	256.67
13	Vona	40	38	29	308.33
14	Newton	42	34	32	305.00
15	Payne	37	33	27	291.67
16	Lovrin 6	33	27	46	291.67
17	F23-71	29	43	31	301.67
18	Blueboy	33	35	32	273.33
19	Plainsman V	48	27	29	273.33
20	OK711248-176	44	30	31	313.33
21	Tam W-102	36	39	25	286.67
22	BPS	45	24	31	221.67
23	TRS237	26	31	30	205.00
24	WA5829	38	38	22	233.33
25	OK72271	44	30	33	268.33
26	TX71A562-6	40	39	30	355.00
27	Tam W-103	56	29	29	246.67
28	NR 31-74	34	34	20	245.00
29	NR 173-75	34	32	32	218.33
30	David	38	31	28	283.33

* High group includes parents with yield greater than 290 g/plot, medium group between 250 and 290 g/plot, and low group less than 250 g/plot.

Table 2. Origin, average yield and yield components for entries grown in 1979, Lahoma.

Parent No.	Entry	Origin	Tiller (No./ 9000 cm^2)	Seeds per spike	Kernel weight (g/ 1000 seeds)	Yield (g/ plot)
7	Turkey	Turkey	70	30	30	418.75
9	Triumph 64	USA (OK)	61	24	37	452.50
8	Scout 66	USA (NB)	66	25	36	475.75
4	Bezostaia 1	USSR	47	34	40	473.75
5	Odesskaya 51	USSR	55	31	41	462.60
6	Priboy	USSR	57	30	45	457.50
1	Osage	USA (OK)	63	31	33	488.75
3	Sturdy	USA (TX)	59	34	32	505.00
2	Tam W-101	USA (TX)	73	23	43	665.00
11	Burgas 2	Bulgaria	54	32	38	571.25
12	Sadovo 1	Bulgaria	48	29	44	498.75
31	NR 72-837	Austria	51	38	29	480.00
13	Vona	USA	67	36	28	636.25
14	Newton	USA (KS)	58	33	35	545.00
15	Payne	USA (OK)	72	30	32	600.25
16	Lovrin 6	Romania	50	27	47	492.50
17	F23-71	Romania	44	46	36	437.50
32	Lovrin 6/T-W-101F6	Rŏm./USA	62	25	47	473.75
26	TX71A562-6	USA (TX)	60	34	33	608.75
27	TAM W-103	USA (TX)	75	30	30	543.75
33	MS TAM 103/ TXR344-6 F1	USA	67	34	34	576.25
34	TXR-Line 344-6	USA (TX)	63	30	32	501.25
35	Dekalb 589	USA	58	24	39	437.50
36	Pioneer HR940	USA	70	25	36	438.75
37	Hart	USA (MO)	65	25	37	453.75
28	NR 31/74	Austria	62	39	34	472.50
29	NR 173/75	Austria	51	34	39	497.50
38	NR 391/76	Austria	49	40	38	501.25
39	Russian	USSR	57	32	39	441.25
40	OK77827	USA (OK)	62	32	28	415.00

* High group includes parents with yield greater than 530 g/plot, medium group between 460 and 530 g/ plot, and low group less than 460 g/plot.

Table 3. Mean squares for tiller number, seeds per spike, kernel weight and yield for 1977, Stillwater and 1978 and 1979, Lahoma and Stillwater.

Year	Location	Tiller	Seeds/Spike	Kernel weight	Yield
1977	Stillwater	395.60**	129.49**	101.12**	19714.80**
1978	Lahoma	151.14**	76.19**	98.02**	19376.25**
	Stillwater	149.29**	65.28**	61.80**	3716.87**
1979	Lahoma	537.90**	684.37**	698.34**	16879.16**
	Stillwater	497.33**	558.73**	842.50**	32453.24**

** Significant at the 0.01 level of probability.

Table 4. The characteristic roots, characteristic vectors and V values for all years and locations.

Year and location	Characteristic root (λ)	Characteristic vectors (a-values) Tiller No. (a_1)	Seeds/ spike (a_2)	Kernel weight (a_3)	V
1977					
Stillwater	0.0310	0.0175	0.0342	0.0486	7.67
(1978)					
Stillwater	0.8159	0.0292	0.0640	0.0546	16.406*
1978					
Lahoma	0.2631	0.0371	0.0366	0.0378	6.318
1979					
Stillwater	0.148	0.0056	0.0086	-0.0054	4.483
1979					
Lahoma	0.6739	0.0165	0.06104	0.0238	14.326**

* Significant at the 0.025 level of probability.

** Significant at the 0.05 level of probability.

The contribution of seeds per spike and kernel weight dominate the function, while the tiller number makes a lower contribution.

For predicting the scores of all the two-way and three-way crosses among the cultivars, the discriminant function was applied to the highest component value of the parent in a cross. Among the 435 possible hybrids involving the 30 cultivars, those with the highest scores belong to the high group and could be promising for increased yield. The 30 top scores for hybrids are shown in Table 5. The hybrid obtained by crossing Lovrin 6(P 16) and F23-71(P 17) has the highest score. By referring to Table 1 the score for a particular hybrid obtained by these two parents was computed as follows:

$$Z = 0.0292(33) + 0.0640(43) + 0.0546(46) = 6.239.$$

The discriminant weights (a-values) are each multiplied by the highest corresponding component (see Table 1) among the two parents. Since it was assumed that the gene action is additive, the discriminant weights should, in fact, be multiplied by the average of component values of the two parental cultivars. However, by selecting in the hybrid population, the high value of yield component should be recovered. Thus this value indicates the potential for selecting high yielding lines within each hybrid population.

The hybrid obtained by Lovrin 6(P 16) and TX71 A562-6(P 26) has the second highest score, since the kernel weight of P16 and seeds per spike of P26 are high (Table 1). The hybrid score was then calculated as:

$$Z = 0.0292(40) + 0.064(39) + 0.054(46) = 6.186.$$

Based on discriminant function associated with 1978 Stillwater and Table 5, parents high in number of seeds per spike and/or kernel weight such as

Lovrin 6(P 16) and F23-71(P 17), should contribute in many of the top crosses.

The three-way crosses for 1978 Stillwater are shown in Table 5. Lovrin 6 (P 16), F23-71(P 17) and Tam W-103(P 27) combine to give the highest score value. Referring to Table 1 the score value is computed as follows:

$$Z = 0.0292(56) + 0.064(43) + 0.0546(46) = 6.906.$$

Osage (P 1) is the second highest in tiller number (Table 1) and combine with Lovrin 6 (P 16) and F23-71(P 17) to give the second highest score.

Comparing parents involved in top two-way and three-way crosses (Table 5), shows that cultivars classified as good parents for two-way crosses were also involved in top three-way crosses.

Cultivars used in 1979 Lahoma (Table 2) were not the same as 1978 Stillwater, but several of them were grown in both nurseries. The λ value (Table 4) for 1979 Lahoma (0.6739) was tested using Wilk's likelihood ratio test criterion. The related V value (14.326) was treated as χ^2 with 6 d.f. and it was significant at the 0.05 level of probability (Table 4). Discriminant weights were computed as mentioned and score value is as follows:

$$Z=0.0165(\text{tiller number}) + 0.06104(\text{seeds/spike}) + 0.0239(\text{kernel weight}).$$

The contribution of seeds per spike dominates the function and the kernel weight ranked second in position. Compared to the discriminant function associated with 1978 Stillwater, the discriminant weight (a value) corresponding to kernel weight at Lahoma is considerably lower.

Table 5. The 30 top two-way and three-way cross scores for 1978 Stillwater.

Two-way crosses				Three-way crosses				
Rank	Parents†		Index score	Rank	Parents†			Index score
1	16	17	6.239	1	16	17	27	6.906
2	16	26	6.186	2	1	16	17	6.703
3	13	16	6.150	3	16	19	17	6.674
4	2	17	6.122	4	11	16	27	6.650
5	16	21	0.081	5	16	21	27	6.650
6	16	24	6.070	6	16	26	27	6.650
7	16	27	6.064	7	2	16	17	6.645
8	17	27	6.010	8	16	22	17	6.587
9	11	16	6.002	9	13	16	27	6.586
10	6	17	5.983	10	16	24	27	6.586
11	14	16	5.953	11	8	16	17	6.558
12	9	17	5.924	12	9	16	17	6.558
13	2	11	5.894	13	16	20	17	6.558
14	2	21	5.894	14	16	25	17	6.558
15	2	26	5.894	15	14	16	17	6.500
16	6	16	5.880	16	6	17	27	6.466
17	6	27	5.878	17	12	17	27	6.466
18	11	27	5.860	18	1	11	16	6.447
19	1	16	5.849	19	1	26	16	6.447
20	1	17	5.843	20	6	16	17	6.442
21	2	13	5.843	21	7	16	17	6.442
22	2	24	5.830	22	13	17	16	6.442
23	5	17	5.830	23	17	26	16	6.442
24	8	17	5.826	24	11	19	16	6.418
25	12	27	5.802	25	19	21	16	6.418
26	16	20	5.770	26	19	26	16	6.418
27	16	25	5.762	27	2	27	17	6.411
28	17	19	5.762	28	5	17	27	6.411
29	17	25	5.746	29	16	18	27	6.394
30	15	16	5.746	30	2	11	16	6.389

† Numbers used as parents represent the entry number.

Table 6. The 30 top two-way and three-way cross scores for 1979 Lahoma.

Two-way crosses				Three-way crosses				
Rank	Parents†		Index score	Rank	Parents†			Index score
1	2	17	5.012	1	16	17	27	5.241
2	17	32	4.975	2	17	32	27	5.241
3	2	38	4.817	3	2	16	17	5.200
4	2	28	4.785	4	2	32	17	5.200
5	32	38	4.780	5	15	16	17	5.180
6	6	17	4.778	6	15	32	17	5.180
7	13	16	4.725	7	6	17	27	5.147
8	13	32	4.752	8	7	16	17	5.139
9	2	31	4.752	9	7	32	17	5.139
10	16	28	4.747	10	16	36	17	5.139
11	32	28	4.747	11	32	36	17	5.139
12	16	17	4.729	12	6	2	17	5.106
13	17	27	4.724	13	12	17	27	5.100
14	16	27	4.721	14	6	15	17	5.086
15	32	27	4.721	15	13	16	17	5.077
16	31	32	4.715	16	13	32	17	5.077
17	2	13	4.687	17	16	33	17	5.077
18	16	33	4.687	18	32	33	17	5.077
19	32	33	4.687	19	2	12	17	5.059
20	15	17	4.663	20	8	16	17	5.057
21	15	16	4.660	21	8	32	17	5.057
22	15	32	4.660	22	2	27	17	5.053
23	6	13	4.658	23	16	38	27	5.046
24	6	28	4.653	24	32	38	27	5.046
25	6	27	4.627	25	7	6	17	5.045
26	27	38	4.623	26	6	36	17	5.045
27	4	2	4.622	27	12	15	17	5.039
28	3	2	4.622	28	16	37	17	5.036
29	2	26	4.622	29	32	37	17	5.036
30	2	33	4.622	30	16	28	27	5.140

† Numbers used as parents represent the entry number.

The top 30 two-way and three-way crosses are shown in Table 6, and they may be evaluated with the same reasoning. A comparison between Tables 5 and 6 shows that results of 1978 Stillwater are in general agreement with the 1979 Lahoma experiment. Lovrin 6 (P 16), F23-71(P 17) and Tam W-103(P 27) contributed in the top score crosses in both experiments. Tam W-101(P 2) and Vona(P 13) were also classified as good parents.

Parental stocks giving a high hybrid score did not need to be from the high yielding group. The combination of Tam W-103(P 27), Lovrin 6(P 16) and F23-71(P 17), which give the highest three-way cross score for both experiments, were from high, medium, and low yield groups, respectively. In a multiple comparison computed separately, these cultivars were significantly different in respect to yield.

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