VARIETAL MIXTURES IN SMALL GRAINS

by

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INTRODUCTION

The presence of mixtures in cereals and other crop seeds constitutes a problem not only to plant breeders and producers of pure "seeds," but also to commercial interests.

The productive capacity of each of the components making up a mixture determines the differences between the relative proportions of the admixtures seeded and harvested. The proportion of one of the components of a mixture will increase under conditions unfavorable to another but not especially detrimental to the increased one. So, the components of a mixture may either increase or decrease as environmental conditions favor or hinder them in their struggle with competing plants.

Several investigators have suggested blending or mixing crop varieties within or among species in order to stabilize and perhaps to maximize production. Blends may offer, theoretically, longer varietal lives, greater stability of production, broader adaptation to environmental conditions, and greater protection against disease. The basic assumption in the utilization of such blends is that the chance for maximum production is subordinated to the principle of stability.

Much of the genetic improvement in self-pollinated crops came through selecting "pure-line" varieties which are uniform in appearance--particularly as to size, maturity, resistance to diseases, high productivity, etc. Nevertheless, there is some evidence that mixtures may yield better than pure lines. The concept of diversification has been little used since the cultivation of mixtures was essentially ended by the discovery of the pure-line theory in late 19th and early 20th centuries.

Natural selection and competition among plants have long been recognized, but the rate at which the changes in cultivated crops occur only recently has been studied. It differs among species in many ways, and the performance of varieties in mixture does not always correlate with the performance when grown separately.

This thesis gives the results of experiments designed to compare the performance of pure lines and their mixtures of winter wheat, which may be considered more or less adapted to Kansas. The study includes, also, the decision dealing with the way by which a multilineal variety is to be formed, that is, whether a mixture is to be reconstituted each season or blended once originally. It was hoped that the results of the experiments might throw some light on the question of genetic variability and obtaining maximum beneficial response of the variety and its environment.

REVIEW OF LITERATURE

Early Studies

Stringfield (25), 1927, and other workers found only occasional indications of small grain yield disturbances from competition. While Love found a correlation between competition and the direction of rows in the field, Stringfield observed no such correlation at all.

Hartley (9), 1939, pointed out that genetic uniformity favored the building up of specialized strains of parasites and obtained mixtures of desirable clones rather than pure stands of a single clone.

Rosen (21), 1949, suggested the culture of mixed populations from a cross without breeding for pure lines as a method of combining resistance to race 45 of Puccinia coronata and Helminthosporium blight in oats.

It is an obvious fact that a genotype may react entirely different in pure culture than under competition. Montgomery (14), 1912, concluded in studies with oats and wheat that a variety which is the best yielder when grown alone may not always dominate in mixtures. On the other hand, a less productive type may be best able to survive competition. He also stated that "for some reason, in almost every case with both wheat and oats two varieties in competition have given a greater yield than when either variety was grown alone."

The fact that the best yielder may not be the best competitor has shown itself to be of wide validity. Harlan and Martini (8), 1938, studied the effect of natural selection in a mixture of barley varieties and found that the variety that would dominate the population quickly was evident. Also, a variety dominant at one location was eliminated at another. Few varieties survived at all locations. Some varieties increased for a time and then decreased.

Klages (12), 1936, reported large increases in the durum components of durum-hard red spring wheat mixtures during abnormal seasons. Likewise, the barley components of various combinations of oats and barley increased.

Laude and Swanson (13), 1942, reported the gradual domination of the Kanred wheat variety over the Harvest Queen variety during a 9-year period in Kansas. Kanred, the better-adapted variety, produced more seed per plant than did Harvest Queen.

Suneson and Wiebe (27), 1942, and Suneson (26), 1949, found a consistent shift from year to year in the proportions of the varieties in barley and wheat mixtures. The highest yielding variety grown singly was not always the dominant variety in the mixture.

Bussel (3), 1937, presented data on the average annual yields per acre obtained from several years testing of oats and barley grown singly and in combination in six New York counties. It was found that the field blend in each case produced as much as or more than the average yields of the components.

Zavitz (28), 1927, presented the results of six years testing of barley, oats, spring wheat, and peas grown separately and in various combinations. In 10 of 11 comparisons made, the average yield of the mixture exceeded that of the crops grown separately.

Ramish and Panse (18) reported that the commercial Malva cotton in India was a stable mixture of Gossypium arboreum var. neglectum and G. hirsutum. In a series of tests of pure and mixed strains, certain mixtures gave yields which were equally as good or better than the pure stock.

Richmond (19), 1943, in a study of intervarietal competition in cotton, viz., in an analysis of varietal yields from replicated four-row plots, found that as an average of all varieties, the outside rows yielded more than the inside rows. This unexpected result suggested the possibility that under certain conditions cotton varieties may "compete" to mutual advantage. However, in an experiment to evaluate varietal mixtures in cotton, Richmond and Lewis (20), 1951, found that there was nothing to be gained in yield by growing mixtures rather than the best variety.

Gustafsson (6), 1953, reported a study of a mixture of three barley varieties. The mixtures were somewhat superior in number of spikes, number of kernels, total kernel weight, and 1000-kernel weight. However, the differences were not striking. The higher number of spikes and kernels worked together with the larger seed size to increase production by some 4 per cent.

A negative attitude towards improvement by means of blending characterized the conclusions of Frankel (5), 1939, who in careful experiments analyzed the yield properties of mixtures and pure strains. "In all nine trials the yield of the blends was closely similar to expectations, only in two out of the nine varieties was there any indication of an increased yield due to blending."

Jensen (11), 1952, worked with the production of multiple pure line oat varieties based on an intra-varietal concept of diversification. He found stable oat production varied from the effects of widespread use of varieties of similar genotypes. A multiline variety blended of compatible lines and uniform in appearance could be a valuable supplement to the recommended single pure line varieties.

Recent Studies

Hadwiger (7), 1955, and Schlehuber and Curtis (23), 1961, found that the yield characteristics of a genotype expressed in a pure stand are not always expressed when grown in competition with other genotypes. In some cases varieties reduced in percentage of the total in any one year were able to return as the predominant variety of the mixture in later years.

Borlaug (2), 1958, proposed that by use of backcrossing, phenotypically similar lines be developed that were genotypically different for certain characters, such as stem rust resistance. There should be 12-16 lines mixed to establish a commercially acceptable multilineal variety. Multilineal varieties produced by Borlaug, by use of a modified backcross method, yielded more than the recurrent parents and also more than the best pure lines.

Elliot (4), 1958, suggested the adjustment of breeding material according to the prevailing environmental conditions. Where adaptation to a large number of microclimates over changing seasons is required of a variety, a number of genotypes of similar phenotype put together might be more advantageous than a single pure line. Conversely, under rigidly controlled and uniform growing conditions a single genotype might be more specifically suited to production than other types of varieties.

Mumaw and Weber (15), 1957, working with soybeans, found that varietal blends as a production practice generally could not be recommended on the basis of yield evaluation. However, other evidence would not discourage entirely the use of certain blends as a cultural practice.

Probst (17), 1957, reported no superiority in yield of the soybean variety blends over the highest yielding variety for the 4-year period studied. The latest maturing variety in a blend matured earlier than the same variety in pure culture.

Allard (1), 1961, found a relationship between the genetic diversity and consistency of performance in different environments. He found that pure-line populations were less stable in productivity than mixtures. Mixtures appear to be insured against very low yields, but the genetic and ecological forces that produce stability in production do not endow mixtures with high average productive capacity.

Pal et al. (16), 1960, studied the intergenotypic competition among 14 varieties of wheat, which belonged to 11 species, and suggested that less competitive varieties may suffer a decrease with regard to some of the components of productivity when grown in a mixture with more competitive varieties, and therefore, have less survival value in such mixtures.

MATERIALS AND METHODS

Six pure lines and four mixtures of winter wheat were studied for five years, 1958 to 1962. The material studied is shown in Table 1.

Table 1. Identification numbers of wheat varieties and mixtures studied, 1958 to 1962 at Manhattan and Hutchinson, Kansas.

Entry No.	Pure lines and mixtures	Selection No.
1	Mediterranean-Hope x Pawnee^3	CI 13112
2	Timstein x Pawnee	52235
3	Sinvalocho x Pawnee^2	52K797
4	Original mixture	
5	New mixture	
6	Pawnee	CI 11669
7	RedChief	CI 12109
8	Bison	CI 12518
9	Original mixture	
10	New mixture	

Entry No. 4, an original mixture, was made up of entries 1, 2, and 3 with a 1:1:1 ratio, respectively. Entry No. 5, the new mixture, was blended the same way except remade every year. Entries 9 and 10 were mixed like 4 and 5 except that entries 6, 7, and 8 composed this mixture. Mediterranean-Hope x Pawnee^3 is characterized by its brown, awned heads, brown seed, and resistance to leaf and stem rusts. Entry No. 2 possesses white glumes, beards, white seed, and many tillers. It is subject to winter killing in Kansas. Entry No. 3 has white glumes, beards, brown seed, and resists leaf rust. The three entries; namely, 1, 2, and 3 mature at about the same time and all have Pawnee in their breeding. Pawnee is a midseason to early variety as far as maturity is concerned. It has brown seed, white glumes, and beards. RedChief is distinguished by its brown glumes and no beards, brown seed, and late maturity. Bison possesses white glumes sometimes with black streaks and brown seed, and is a midseason to late in maturity. All three were or are important commercial varieties in Kansas.

The seed was obtained from the Kansas State University Wheat Breeding project at Manhattan, Kansas, and was planted in randomized complete block designs at Manhattan and Hutchinson, Kansas from 1958 to 1962. Each pure line and mixture were replicated four times at each location. Each plot contained four 9.6-foot rows and 19.2 square feet was harvested (two center rows) for yield and test weight studies. Plants in one-half of the first row in the first plot of each pure line, and the entire row in the four plots in case of mixtures, were cut to represent random samples from which the distributions of pure lines within the mixtures, based on head color and awns, were determined. For yield studies, four observations were taken for each pure line and mixture at each location in every year. Only one measurement was taken for test weight study by mixing the seed of three plots as a result of seed deficiency.

EXPERIMENTAL RESULTS

Yield Data

The yield data were recorded in grams per plot at both Manhattan and Hutchinson, Kansas, in the years 1958, 1959, 1960, 1961, and 1962. In order to facilitate computations, 200 was subtracted from each of the whole determinations. Table 2 gives the coded mean yields of the first five entries (1-5) and the ranks of each entry for five years at Hutchinson and Manhattan. Table 3 gives the same information on the other five entries (6-10).

Data in Tables 2 and 3 show the different ranks occupied by the mean yields for the first three pure lines, second three pure lines, and mixtures. These various responses probably were due to different environmental conditions and diseases that resulted in shifting ranks. For example, Table 2 shows that pure line No. 1 ranked first in 1960 at both Manhattan and Hutchinson, Kansas. This could have been due to its greater resistance to stem rust. Pure line No. 2 ranked fifth at both locations, in 1960, due to winter killing. In 1962, this same pure line ranked fourth at Manhattan, and fifth at Hutchinson, possibly because of moisture deficiency in the spring.

All of the data were analyzed statistically in order to show the significance of both main effects; namely, pure lines and mixtures, years, and locations; and their first- and second-order interactions. The analysis is given in Table 4.

Data in Table 4 show that significant differences occurred among the average yields of pure lines and mixtures. Also, the differences between both the average yields of years and those of locations were significant. All interactions but one, namely pure lines and mixtures x locations, showed significance.

Table 2. Coded mean yields and their rank-order for the first five pure lines and mixtures at Manhattan and Hutchinson, Kansas, 1958 to 1962.

	Manhattan									
	Pure lines and mixtures									
	1		2		3		4		5#	
Years	m.[1]	r.[2]	m.	r.	m.	r.	m.	r.	m.	r.
1958	139	3	96	5	167	1	128	4	156	2
1959	109	5	187	1	150	3	160	2	116	4
1960	313	1	-25	5	68	4	170	3	252	2
1961	287	5	299	2	291	4	297	3	343	1
1962	221	1	170	4	146	5	186	3	197	2

	Hutchinson									
	Pure lines and mixtures									
	1		2		3		4		5#	
Years	m.	r.	m.	r.	m.	r.	m.	r.	m.	r.
1958	137	1	82	5	111	4	119	2	115	3
1959	120	2	83	5	113	3	91	4	153	1
1960	188	1	27	5	153	4	156	2	156	2
1961	371	2	376	1	316	5	340	3	328	4
1962	185	2	158	5	199	1	171	4	173	3
Mean of 10 tests	207		145		171		182		199	

[1] Coded mean yields in grams.

[2] Rank-order of 1, etc.

\# L.S.D. = 59 grams per plot at the 5% level of significance.

Table 3. Coded mean yields and their rank-order for the second five pure lines and mixtures at Manhattan and Hutchinson, Kansas, 1958 to 1962.

	Manhattan									
	Pure lines and mixtures									
	6		7		8		9		10*	
Years	m.[1]	r.[2]	m.	r.	m.	r.	m.	r.	m.	r.
1958	132	5	150	2	167	1	134	4	138	3
1959	149	1	92	4	124	2	76	5	119	3
1960	123	3	119	4	200	1	161	2	104	5
1961	297	2	186	5	283	3	320	1	272	4
1962	181	1	157	5	173	2	168	3	161	4

	Hutchinson									
	Pure lines and mixtures									
	6		7		8		9		10*	
Years	m.	r.	m.	r.	m.	r.	m.	r.	m.	r.
1958	98	3	75	5	163	1	92	4	114	2
1959	84	5	89	4	96	2	96	2	107	1
1960	139	3	101	5	123	4	148	1	142	2
1961	364	1	320	2	300	5	313	3	310	4
1962	149	5	218	1	209	3	213	2	206	4
Mean of 10 tests	172		151		184		172		167	

[1] Coded mean yields in grams.

[2] Rank-order of 6, etc.

* L.S.D. = 59 grams per plot at the 5% level of significance.

Table 4. Analysis of variance of yield for the wheat pure lines and mixtures grown at both Manhattan and Hutchinson, Kansas, 1958 to 1962.

Source of variation	D.F.	S.S.	M.S.	F
Pure lines and mixtures	9	130,274.8	14,475.9	8.12**
Years	4	2,044,576.0	511,144.0	286.72***
Location: Manhattan and Hutchinson, Kansas	1	15,438.0	15,438.0	8.66**
Pure lines and mixtures x years	36	292,389.8	8,121.9	4.56*
Pure lines and mixtures x locations	9	6,544.2	727.1	0.41 ns
Years x locations	4	65,601.9	16,400.5	9.19**
Pure lines and mixtures x years x locations	36	184,493.6	5,124.7	2.87*
Error	300	534,805.7	1,782.7	
Total	399	3,274,114.0		

* Significant.

** Highly significant.

*** Very highly significant.

ns = Not significant.

Since the F-test for pure lines and mixtures was significant, some averages of either pure lines or mixtures are equal or, at least, their differences are not true and due to the chance. In order to justify the latter statement some comparisons between the total yields of pure lines and mixtures were made. Such results are shown in Table 5.

Table 5. Statistical analysis of comparisons between the total yields of pure lines and mixtures at Manhattan and Hutchinson, Kansas, 1958 to 1962.

Comparison	D.F.	S.S.	M.S.	F
Entries 1, 2, and 3 vs. 4	1	1,595.1	1,595.1	0.89 ns
Entries 1, 2, and 3 vs. 5	1	17,739.0	17,739.0	9.05**
Entry 4 vs. 5	1	5,797.0	5,797.0	3.27 ns
Entries 6, 7, and 8 vs. 9	1	328.3	328.3	0.18 ns
Entries 6, 7, and 8 vs. 10	1	46.3	46.3	0.03 ns
Entry 9 vs. 10	1	414.1	414.1	0.23 ns
Error	300	534,805.7	1,782.7	

** Highly significant.
ns Not significant.

Data in Table 5 show that significant difference was found between the pure lines 1, 2, and 3 and mixture No. 5 as far as the average yield is concerned. This means that the average yield of these pure lines is significantly different from that of the new mixture (entry No. 5). Because the average yield of this mixture was greater than that of pure lines, it was concluded that the average yield of entry No. 5 was significantly superior to that of its components. But, on the other hand, the remaining five contrasts showed no significance which indicates that their average yields are equal,and the differences that existed among them were due to chance.

In checking the data in Tables 2 and 3 the mean yields ranked differently among the first three pure lines, second three pure lines, and mixtures from year to year and one location to another. This emphasized the significances obtained in Tables 4 and 5.

Since the mean yield for pure lines and mixtures was significantly different, as shown in Table 4, the L.S.D. was calculated on the basis of the error variance to be 59 grams per plot. These means were arrayed and lineated by means of the L.S.D. for both Manhattan and Hutchinson, Kansas, in 1958 to 1962, as shown in Tables 6 and 7.

Data in Tables 6 and 7 show either homogeneity of heterogeneity of the mean yields for all pure lines and mixtures. No constant trend to either superiority or inferiority occurred as far as pure lines and mixtures are concerned. In other words, the mean yields of pure lines showed either equality, inferiority, or superiority to those of their mixtures during the years of study at both locations.

Data in Table 6 show that the average yield of entry No. 4 was not significantly better or worse than those of entries 1, 2, and 3 at Manhattan in 1958, 1959, 1961, and 1962. This original mixture (entry No. 4) was significantly better than entries 2 and 3 and worse than entry No. 1 in 1960. The mean yield of entry No. 5 did not differ significantly from those of entries 1, 2, and 3 in 1961 and 1962. The new mixture (entry No. 5) was better than entry No. 2 in 1958 and entries 2 and 3 in 1960, while it was

Table 6. Ordered array of coded mean yields for all pure lines and mixtures at Manhattan, Kansas, 1958 to 1962.

Years:	Pure lines, mixtures, and their means[1]									
1958	3	8	5	7	1	10	9	6	4	2
	167	167	156	150	139	138	134	132	128[2]	96
1959	2	4	3	6	8	10	5	1	7	9
	187	160	150	149	124	119	116	109	92	76
1960	1	5	8	4	9	6	7	10	3	2
	313	252	200	170	161	123	119	104	68	-25
1961	5	9	2	4	6	3	1	8	10	7
	343	320	299	297	297	291	287	283	272	186
1962	1	5	4	6	8	2	9	10	7	3
	221	197	185	181	173	170	168	161	157	146

[1] L.S.D. = 59 grams per plot at 5% level of significance.

[2] All means above the same line are similar.

Table 7. Ordered array of coded mean yields for all pure lines and mixtures at Hutchinson, Kansas, 1958 to 1962.

Years:	Pure lines, mixtures, and their means[1]									
1958	8	1	4	5	10	3	6	9	2	7
	163	137	119	115	114	111 [2]	98	92	82	75
1959	5	1	3	10	8	9	4	7	6	2
	153	120	113	107	96	96	91	89	84	83
1960	1	4	5	3	9	10	6	8	7	2
	188	156	156	153	148	142	139	123	101	27
1961	2	1	6	4	5	7	3	9	10	8
	376	371	364	340	328	320	316	313	310	300
1962	7	9	8	10	3	1	5	4	2	6
	218	213	209	206	199	185	173	171	159	149

[1] L.S.D. = grams per plot at 5% level of significance.

[2] All means above the same line are similar.

worse than entry No. 2 in 1959 and entry No. 1 in 1960. Otherwise, this mixture equalized the pure lines.

From Table 7, it might be noticed that the mean yield of entry No. 4 at Hutchinson was not different significantly from those of entries 1, 2, and 3 in 1958, 1959, 1961, and 1962. But on the other hand, entry No. 4 was better than entry No. 2 and equal to entries 1 and 3 in 1960. Entry No. 5 equalized entries

1, 2, and 3 in 1958, 1961, and 1962 while it exceeded entry No. 2 in both 1959 and 1960. Entries 9 and 10 showed various results as observed from Table 7.

Test Weight Data

The test weight was recorded in the years 1958 to 1962 at both Manhattan and Hutchinson, Kansas, in pounds per bushel, using a standard pint test weight kettle. Analysis of variance for the five years of data are summarized in Table 8.

Table 8. Analysis of variance of test weight data at Manhattan and Hutchinson, Kansas, 1958 to 1962.

Source of variation	D.F.	S.S.	M.S.	F
Pure lines and mixtures	9	160.34	17.82	42.43**
Years	4	281.26	70.32	167.43***
Locations: Manhattan and Hutchinson, Kansas	1	52.56	52.56	125.14***
Pure lines and mixtures x years	36	70.24	1.95	4.64*
Pure lines and mixtures x locations	9	8.51	0.95	2.26*
Years x locations	4	92.38	23.10	55.00**
Pure lines and mixtures x years x locations (Error variation)	36	15.19	0.42	
Total	99	680.48		

* Significant.

** Highly significant.

*** Very highly significant.

Data in Table 8 show that significant F-tests were found for both main effects and first-order interactions. The second-order interaction was used as the error variance since the real error was equal to zero because the grains of three replicates out of four were mixed together for each pure line and mixture at both Manhattan and Hutchinson, Kansas, in 1958 to 1962 in order to enlarge the amount of seed for test weight. Since there was one observation for each pure line and mixture in any year or at any location, the rank-order of the mean test weights was based upon the pooled sums of pure lines and mixtures for the whole years and locations and not separately as was done with the yield. The data obtained are given in Tables 9 and 10.

Table 9. Mean test weights and their rank-order for the first five pure lines and mixtures based on pooled sums at Manhattan and Hutchinson, Kansas, 1958 to 1962.

Pure lines and mixtures	Test weight lbs. per bu.	Ranks
Mediterranean-Hope x Pawnee[3]	58.9	1
Timstein x Pawnee	57.5	5
Sinvalocho x Pawnee[2]	57.9	4
Original mixture	58.3	2
New mixture	58.3	2

Table 10. Mean test weights and their rank-order for the second five pure lines and mixtures based on pooled sums at Manhattan and Hutchinson, Kansas, 1958 to 1962.

Pure lines and mixtures	Test weight lbs. per bu.	Ranks
Pawnee	59.6	3
RedChief	62.1	1
Bison	59.6	3
Original mixture	59.5	5
New mixture	60.2	2

From Tables 9 and 10 it might be observed that the mean test weights for pure lines and mixtures ranked differently when their pooled sums were taken into account. Mediterranean-Hope x Pawnee[3], or entry No. 1, ranked first and showed superiority only among the first five entries. RedChief was superior among entries 6 through 10.

There were significant differences between the mean test weights of pure lines and mixtures. As the grain of RedChief, pure line No. 7, was the heaviest in all comparisons, some interesting contrasts were analyzed statistically which are summarized in Table 11.

Data in Table 11 show that significant differences were found between the mean test weights of RedChief and all others. The mean test weights for the second three pure lines and entry No. 9 were significantly different as well as those of entries 9 and 10. Other contrasts are considered to be equal.

Table 11. Statistical analysis of comparisons between the total test weights of pure lines and mixtures at Manhattan and Hutchinson, Kansas, 1958 to 1962.

Comparison	D.F.	S.S.	M.S.	F
Entries 1, 2, and 3 vs. 4	1	0.23	0.23	0.55 ns
Entries 1, 2, and 3 vs. 5	1	0.34	0.34	0.81 ns
Entry 4 vs. 5	1	0.01	0.01	0.02 ns
Entries 6, 7, and 8 vs. 9	1	6.17	6.17	14.69**
Entries 6, 7, and 8 vs. 10	1	0.23	0.23	0.55 ns
Entry 9 vs. 10	1	2.66	2.66	6.33*
Error	36	15.19	0.42	

* Significant.
** Highly significant.

Multiple comparisons were made between all entries studied. The L.S.D. at the 5 per cent level of significance was used to determine the homogeneity and heterogeneity of test weight means. L.S.D. calculated on the basis of the error variance was 0.6 pound per entry. Test weight means were arrayed and lineated as follows:

7	10	8	6	9	1	5	4	3	2
62.1	60.2	59.6	59.6	59.5	58.9	58.3	58.3	57.9	57.5

The above data emphasizes the significant differences obtained in Table 11. These multiple comparisons show that

RedChief, entry No. 7, had the highest mean test weight. Other pure lines and blends varied in their responses from year to year and by location.

Glume Color and Awns

The only glume color and awn data recorded at Manhattan and Hutchinson in 1962 were used in this study. The separation of heads within mixtures was done on the basis of both color and either presence or absence of awns, as the heads of each pure line have their distinguishable characteristics (see Table 1).

The separation of pure lines within mixtures included only the brown-awned from the white-awned heads, for the pure lines 1, 2, and 3, and the brown-awnless from the white-awned ones, for the pure lines 6, 7, and 8. Entries 2 and 3 were not separated from each other or entries 6 and 8. Average percentages of pure line distributions within the mixtures are shown in Tables 12 and 13.

Table 12. Distribution of entry 1 versus entries 2 and 3 based on glume color at Manhattan and Hutchinson, Kansas, in 1962.

	Average percentages					
	Manhattan			Hutchinson		
Mixtures	BA[1]	WA[2]	O[3]	BA	WA	O
Entry 4	33.9	64.8	1.3	47.6	52.1	0.3
Entry 5	26.7	72.0	1.3	25.3	74.4	0.3

[1] Brown-awned glumes.

[2] White-awned glumes.

[3] Off-types.

Table 13. Distribution of entry 7 versus entries 6 and 8 based on glume color and awns at Manhattan and Hutchinson, Kansas, 1962.

Mixtures	Average percentages					
	Manhattan			Hutchinson		
	BAS[1]	WA[2]	O[3]	BAS	WA	O
Entry 9	12.7	82.4	4.9	20.0	77.5	2.5
Entry 10	25.8	72.9	1.3	30.3	68.9	0.8

[1] Brown-awnless glumes.
[2] White-awned glumes.
[3] Off-types.

The presence of off-types is low, indicating that cross-pollination occurred infrequently. The off-types that existed within entries 4 and 5 were characterized by the intermediate brown color and the decreased awn length of heads. Those distributed within entries 9 and 10 showed three kinds of characteristics. Some heads were white and awnless, others brown and awned, and still others light brown and awned. These off-types possibly resulted from cross-pollination between pure lines when grown in mixtures or alongside each other. The distribution of such types was the least frequent, although it was a little larger in entry 9 as compared to that of other blends.

It is evident in Table 12 that the average percentages of Mediterranean-Hope x Pawnee^3 in entry 5 was less than one-third. This was not as expected from the first year of the blend. Table 12 also shows that the distribution of Mediterranean-Hope x Pawnee^3 among entry 4 at Manhattan was one-third as expected while it exceeded one-third at Hutchinson.

Data in Table 13 show that RedChief was 25.8 instead of 33.3 at Manhattan but 30.3 at Hutchinson. Table 13 shows also that the distribution of RedChief within entry 9 at Manhattan and Hutchinson to be lower than one-third.

Most of these results deviated from the expected ones. Such deviations were tested by the X^2-test of significance which is indicated in Table 14.

Table 14. X^2-test for the distribution of white-awned, brown-awned, and brown-awnless heads in all mixtures at Manhattan and Hutchinson, Kansas, in 1962.

Mixtures	X^2 values[1]	
	Manhattan	Hutchinson
Entry 4	1.03	185.84**
Entry 5	22.42*	56.37*
Entry 9	234.21**	145.41**
Entry 10	28.76*	7.11*

[1] $X^2_{.05}$, 1 D/F = 3.84.
* Significant.
** Highly significant.

The analysis suggests that the observed distributions showed significant deviations from those expected except for entry 4 (original mixture) at Manhattan. This means that the distribution of pure lines in the mixtures not only varied among mixtures but also between locations. Thus, according to X^2-tests it was shown that Mediterranean-Hope x Pawnee[3] pure line increased significantly at Hutchinson in the original blend (entry 4). By the same interpretations, the increase and dominance of both Pawnee and Bison at both locations over RedChief were significant. This leads to the conclusion that competition among pure lines within their composites exists, at least under the present conditions.

DISCUSSION

The pure lines studied in this experiment were advanced ones being considered as potential varieties, each of which may be more or less adapted to local environmental conditions. The history of the pure lines was known as far as their performance was concerned. The variety x year interaction was also known to be usually significant in the wheat variety trials in the Great Plains, as was found by Salmon (22) from previous yield trials.

In this experiment, only one of the four mixtures yielded better than the average of the three pure lines composing it. The mixtures never ranked the lowest as compared to their components at both Manhattan and Hutchinson, Kansas, in the five years studied except entry No. 9 in 1959 at Manhattan. Entry 5 was first in 1961 at Manhattan and in 1959 at Hutchinson. Mediterranean-Hope x Pawnee^3 was generally superior among others at Hutchinson in all years, while at Manhattan various ranks were observed. Timstein x Pawnee, and Sinvalocho x Pawnee^2 showed variable results. Mediterranean-Hope x Pawnee^3 made up 47.60 per cent of the original mixture at Hutchinson in 1962 and about one-third at Manhattan.

After five years, RedChief made up only 12.70 per cent of its mixture at Manhattan and 20.00 per cent at Hutchinson. These results illustrate that the competitive ability of a variety or pure line in a mixture cannot always be accurately judged by its response in vigor, reproductive capacity, etc., in pure stands, as indicated by Schlehuber and Curtis (23).

Natural selection could be expected to favor the most productive genotypes in a mixture at one location. For example, Mediterranean-Hope x Pawnee[3] pure line gave a high significant percentage in entry 4 (original mixture); i.e., 47.60 per cent at Hutchinson, Kansas in 1962. Location effect was significant and provided an indication of a different environmental effect.

The existence of first-and-second-order interactions, which were tested as a three-way contingency table, indicated that no independence was exhibited between pure lines and mixtures, years, and locations. Accordingly, the pure lines and mixture effect was not independent of the effect of years and/or location, as found by Hadwiger (7).

The results obtained do not provide a direct clue that would add a new possibility of competition for mutual advantage as suggested by Richmond (19), or cooperation between genotypes as found by Gustafsson (6), since the composites did not show consistent superiority over pure lines. Differences in physiological requirement and growth rhythm of the component pure lines may create better conditions for the individual plant in a blend than in a pure stand, provided the requirements of all members are closely alike. Such cases did not exist as the mixtures yielded neither better nor worse than their components under adverse or normal conditions. Only one mixture proved to be significantly different from its pure lines while the other three equalized their composites as far as yield is concerned.

A number of experimenters have discussed in detail the analysis of data from experiments established simultaneously at a number of places and at the same place for a number of years. Since the pure line and mixture x location interaction was found to be not significant, Horner and Frey's (10) suggestions to decrease such interaction was proved but still a significant year x pure line and mixture interaction does not solve the problems. Farmers want to know what varieties are most probably to be best for a period of years. The idea of using the year x pure line and mixture interaction as the error term does not apply with the present work since the experimental design was different from that used by Siddig (24), even though the same locations were used.

It is well known that a certain amount of heterozygosity or heterogeneity, or both may provide a broad adaptation base. In such case the preservation of broad adaptation can be maintained by propagating varieties of wheat, as blends or mixtures.

The plant breeder has four solutions to overcome the unavoidable variation of environmental factors. He may produce a wider adaptable variety. He may develop high specialized varieties suitable for more narrowly confined conditions where climate conditions stay relatively constant. He may cultivate a number of more or less similar pure lines that would meet the effect of seasonal fluctuation. Or, finally, he may sow pure lines in mixture, a proposal which would be difficult to conceive under our present hypotheses of purity. These suggestions were proposed by Siddig (24).

Results in this experiment showed a great diversity for the pure lines and mixtures as far as yield, test weight, and head counts are concerned. This study does not solve the problem of preferring the cultivation of either pure lines or blends. Theoretically, the concept of diversification holds true. But with a thorough knowledge of the characteristics of the pure lines and the data of performance, the plant breeder would be able to blend reasonably compatible lines in proper proportions. Such variety, called a multiline variety by Jensen (11), should be uniform for many acceptable characteristics. In such case, farmers may readily accept these new "mixed" varieties if the latter perform better than the pure lines. For example, Rodco wheat has been grown commercially in Kansas since 1958 and on an estimated 5.6 per cent of the 1962 Kansas wheat acreage. Moreover, this variety, which is considered to be a "mixed" variety, has been accepted by farmers probably because of the complementary characteristics of the two varieties making up the blend. The red component has weak straw, and "mellow" gluten which is complemented by strong straw and strong gluten of the white variety. The red variety resists soil-borne mosaic and wheat streak mosaic while the white portion resists stem and leaf rust and hessian fly. Such a blend has been successful and accepted by Kansas farmers.

It is suggested that further investigations are needed to solve the problems of the varietal mixtures in small grains.

SUMMARY AND CONCLUSIONS

Four mixtures of hard red winter wheat were compounded from six different pure lines and studied at Manhattan and Hutchinson, Kansas, in the years 1958 to 1962. Randomized complete block designs were conducted to compare the performance of the pure lines and mixtures. The series at each location consisted of four replications.

The mean yields of the pure lines and mixtures differed significantly as well as those of years, locations, and all but one interaction. The average yield of one mixture was significantly superior to that of the three components at both Manhattan and Hutchinson, Kansas, during the five years studied. Other mixtures equaled their pure lines. Therefore, it cannot be concluded that the mixtures may or may not yield better than their pure components.

The test weights of pure lines and mixtures were significantly different. RedChief was superior to all entries.

A significant increase of Mediterranean-Hope x Pawnee[3] occurred in the mixture at Hutchinson, Kansas during the period 1958 to 1962, which means that natural selection favored this selection at this location. RedChief decreased significantly at both locations in original and new mixtures (entries 9 and 10, respectively). Other distributions showed various results.

No conclusion could be drawn since a variety of results were obtained. In order to solve the problems of the application of the mixture concept, further investigations over longer periods of time and at several locations are needed.

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LITERATURE CITED

(1) Allard, R. W.
Relationship between genetic diversity and consistency of performance in different environments. Crop Sci. 1: 127-133, 1961.

(2) Borlaug, N. E.
The use of multilineal or composite varieties to control airborne epidemic diseases of self-pollinated crop plants. First International Wheat Genetics Symposium at the University of Manitoba, Winnipeg, Manitoba, Canada. Aug. 11 to 15. pp. 12-27, 1958.

(3) Bussel, F. P.
Oats and barley on New York farms. Cornell Ext. Bul. No. 376, 1937.

(4) Elliot, Fred C.
Plant breeding and cytogenetics. New York: McGraw-Hill, 1958.

(5) Frankel, O. H.
Analytical yield investigation on New Zealand wheat IV blending varieties. Jour. Agr. Sci. 29: 249-261, 1939.

(6) Gustafsson, A.
Cooperation of genotypes in barley. Hereditas 39: 1-18, Jan., 1953.

(7) Hadwiger, L. A.
The reaction of four hard red winter wheat varieties in a composite. A Master of Science Thesis. Oklahoma State Univ., 1955.

(8) Harlan, H. V., and M. L. Martini.
The effect of natural selection in a mixture of barley varieties. Jour. Agr. Res. 57: 189-199, March, 1938.

(9) Hartley, C.
The colonal variety for tree planting asset or liability? Arborists News 4: 25-27, 1939. (Cited by Jensen [11].)

(10) Horner, T. W., and K. J. Frey.
Methods for determining natural areas for oat varietal recommendations. Amer. Soc. Agron. Jour. 49: 313-315, June, 1957.

(11) Jensen, N. F.
Intra-varietal diversification in oat breeding. Amer. Soc. Agron. Jour. 44: 30-34, Jan., 1952.

(12) Klages, K. H.
Changes in the proportions of the components of seeded and harvested cereal mixtures in abnormal seasons. Amer. Soc. Agron. Jour. 28: 935-940, 1936.

(13) Laude, H. H., and A. F. Swanson.
Natural selection in varietal mixtures of winter wheat. Amer. Soc. Agron. Jour. 34: 270-274, 1942.

(14) Montgomery, E. G.
Competition in cereals. Nebr. Agr. Exp. Sta. Bul. No. 127, 1912.

(15) Mumaw, C. R., and C. R. Weber.
Competition and natural selection in soybean varietal composition. Agron. Jour. 49: 154-162, 1957.

(16) Pal, B. P., Y. M. Upadhyaya, H. R. Khan, and S. Ramanujam.
A study of survival in a mixture of fourteen varieties of wheat. Ind. Jour. Gen. & Plt. Breed. 20: 102-112, 1960.

(17) Probst, A. H.
Performance of variety blends in soybeans. Agron. Jour. 49: 148-150, 1957.

(18) Ramiah, K., and V. G. Panse.
Growing of mixtures. Indian Central Cotton Committee, Second conference on cotton growing problems in India. Bombay, India. p. 92.

(19) Richmond, T. R.
Competition in cotton variety tests. Amer. Soc. Agron. Jour. 35: 606-612, 1943.

(20) ____________, and C. F. Lewis.
Evaluation of varietal mixtures in cotton. Amer. Soc. Agron. Jour. 43: 66-70, 1951.

(21) Rosen, H. R.
Oat percentage and procedure for combining resistance to crown rust, including Race 45 and Helminthosporium blight. Phytopath. 39: 2, 1949.

(22) Salmon, S. C.
Analysis of variance and long-time variety tests of wheat. Amer. Soc. Agron. Jour. 43: 562-570, Nov., 1951.

(23) Schlehuber, A. M., and B. C. Curtis.
Grain yield of four varieties of hard red winter wheat in pure stands compared to a mixture. Okla. State Univ. Exp. Sta. Processed Series. p. 394, Dec., 1961.

(24) Siddig, M. A.
Evaluation of pure lines, purified bulks, and the original wheat strain in performance trials. A Master of Science Thesis. Kans. State Univ., 1959.

(25) Stringfield, G. H.
Intervarietal competition among small grains. Amer. Soc. Agron. Jour. 19: 971-983, 1927.

(26) Suneson, C. A.
Survival of four barley varieties in a mixture. Agron. Jour. 41: 459-461, 1949.

(27) ____________, and G. A. Wiebe.
Survival of barley and wheat varieties in mixtures. Amer. Soc. Agron. Jour. 34: 1052-1056, 1942.

(28) Zavitz, C. A.
Forty years' experiments with grain crops. Ontario Agr. College Bul. No. 332, 1927.

VARIETAL MIXTURES IN SMALL GRAINS

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Many researchers have reported the superiority of interspecific or intervarietal blends in agricultural crops as compared to their corresponding pure components. As has been suggested by different workers, a multiline variety would be theoretically expected to possess the characteristics of greater protection against disease, greater stability in production, broader adaptation base, and longer varietal life.

It was the purpose of this paper to report the results of an experiment designed to compare the pure lines and their mixtures as far as yield and test weight are concerned.

A randomized complete block design was employed of four replicates at Manhattan and Hutchinson, Kansas, in the years 1958 to 1962, inclusive. The first three pure lines were the components of the first two mixtures, the first called the "original" mixture because the seed was blended in 1957 and grown continuously. The other was referred to as the "new" mixture because it was blended anew each year. The second three pure lines composed the second two mixtures which were called "original" and "new" for the same mentioned reason.

Yield in grams per 19.2 square foot plot, test weight in pounds per bushel, and head distribution on the basis of color and awns were recorded during the study.

The yields of the pure lines and mixtures differed significantly as well as those of years, locations, and all but one interaction. One mixture yielded significantly better than the average of its components during the years of study at both locations. Other mixtures were as much as pure lines.

Significant differences were also found between the test weights of the pure lines and mixtures included in the study. One pure line, RedChief, increased the test weight in the mixture containing it. The mixture (entry No. 10) blended each year gave a significantly higher test weight than that originated from the start, probably because of the decrease of RedChief in the original mixture. However, this mixture gave a significantly lower test weight than RedChief. Regarding the distribution of the pure lines among mixtures, one pure line showed a significant increase at only one location as the result of natural selection effect. Even though RedChief had a high test weight, it decreased significantly at both locations. Other distributions varied widely.

As the climatic conditions varied each year at both locations, the variable conditions showed no specific selection effect in the mixtures.

No conclusions could be drawn as various results were obtained. However, blends of compatible and complementary lines should be possible. The individual component lines would be retained and withdrawals or additions could be made of promising new selections at any time.