EVALUATION OF PURE LINES, PURIFIED BULKS, AND THE ORIGINAL WHEAT STRAIN IN PERFORMANCE TRIALS

by

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B. S., University of Khartoum, Sudan, 1957

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1959

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INTRODUCTION

The concept of a broad adaptation base for agricultural varieties is by no means a new one. Pre-Mendelian plant breeders often used mass selected stocks and maintained desired types by frequent reselection. After the rediscovery of Mendel's work and Johannsen's announcement of the pure line theory, the progeny row method of breeding was widely employed to develop "pure line" varieties.

Recently there has been a renewed interest in maintaining some variability in the varieties of self-fertilized crops. Such a variety would be expected on theoretical grounds to possess the characteristic of longer varietal life, greater stability of production, broader adaptation to environment and greater protection against disease. The basic assumption in the utilization of such a variety is that the chance for maximum production is subordinated to the principle of stability.

This paper gives the results of experiments designed to compare the performance of pure lines, purified bulks, and original strains of twenty-six promising advanced lines of winter wheat, which may be considered more or less adapted to Kansas. It was hoped that the results of the experiments may throw some light on the question of genetic variability and obtaining maximum beneficial response of the variety and its environment.

REVIEW OF LITERATURE

Harland (12) described the environment as a constantly changing succession of environmental niches to which the genotypes are being constantly adjusted by differential survival rates. He stated that there was sufficient evidence indicating a loss of 10 per cent or more in yield by the use of pure lines in cotton. He pointed out further that the plant breeder should adjust genetic variance in his crop to the environmental complex with which it must cope.

Knight and Rose (18) report that the variations in environmental conditions can be met by the production of numerous strains or by a breeding policy based on varietal plasticity, used in the sense of ability of a variety to yield well over a wide range of environments. They pointed out that in line breeding the genes become "fixed" and there is little possibility of subsequent elimination of subnormal genotypes. It follows that loss of varietal plasticity is inherent in this method of breeding.

Elliot (7) suggests 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.

Grafius and Dirks (10) advocated strongly the breeding for local adaptation. They say that it was always possible to find local varieties which had relative percentage yield equal to or greater than the "universal", and that the data they had indicated clearly that the local variety may be markedly superior when night temperature is involved.

Horner and Frey (14) examined the data from oat varieties grown at nine locations in Iowa for a period of five years, from the standpoint of subdividing the state into subareas which minimized variety X location interaction within the subareas. Optimum patterns of subdivision into two, three, four, and five subregions resulted respectively in an 11 per cent, 21 per cent, 30 per cent, and 40 per cent decrease in the average variety-location component within sections compared to the same statistics for the state as a whole.

Another approach to the problem of maintaining purity or variability in a stand of agricultural crops has been from the point of view of disease control.

Hartley (13) pointed out that genetic uniformity favored the building up of specialized strains of parasites and advocated mixtures of desirable clones rather than pure stands of a single clone.

Steven and Scott (28) also believed that maintaining genetic uniformity makes conditions more favorable to rapid increase of an adapted pathogenic race or species. On the basis of past variety pathogen relationships, they predicted the probable life of new oat varieties in the central corn belt to be four to five years.

On the other hand, Caffery (3) indicated that a mixed population of host plants might favor the evolution of biologic forms of plant pathogen.

Rosen (24) suggested the culture of mixed populations from a cross without breeding for pure lines as a method of combining resistance to race 45 of _Puccina coronata_ and Helminthosporium blight in oats.

Jensen (15) advocated that there was no inherent disadvantage in the use of multiline varieties and that controlled mixtures might offer considerable insurance against disease in oats.

It was suggested by Borlaug and Gibler (1) that a composite variety be developed which would include genes from a number of disease-resistant wheats. Lines phenotypically similar carrying different genes for resistance, would be grown separately and the seed mechanically mixed to form a composite variety, as races of the rust organism changed lines could be dropped or added.

It is an intriguing fact that a genotype may react entirely differently in pure culture than under competition. Montgomery (20) 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 pointed out 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 sown alone."

The fact that the best yielder may not be the best competitor has shown itself to be of wide validity. Harlan and Martini

(11) working with barley mixtures found evidences of differences in aggressiveness and consequent population shifts among components of the mixtures they studied; different varieties dominated the mixture in different environments.

Klages (17) working with mixtures of oats and barley and mixtures of hard red spring and durum wheats, found that marked changes in population took place within one season. In the case of wheat mixtures differences in stem rust resistance were associated with population changes.

Laude and Swanson (19), after studying mixtures of wheat varieties, came to the conclusion that there was a gradual domination of the mixture by a better adapted variety over a nine-year period.

Suneson and Wiebe (29) found a consistent shift from year to year in the proportions of varieties in a barley mixture. The highest yielding variety grown singly did not become the dominant variety in the mixture, nor was there any apparent correlation between disease resistance and selective advantage.

The problem of mixtures yielding higher than any of their components in pure form, suggested by Montgomery, has been studied with intra- and interspecfic mixtures.

Bussel (2) 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 single yields.

Zavitz (31) 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 (21) 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 (22) 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 (23) found that there was nothing to be gained in yield by growing mixtures rather than the best variety.

Gustafsson (9) 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 four per cent.

Kiesselbach (16) reported the annual yields of 31 strains of Turkey wheat compared with the original Turkey from which they were selected. Examination of the average relative yields for five years (1914-18) and four years (1919-22) showed that

27 of the 31 strains yielded lower in relation to the original Turkey in the second period than in the first.

In most of the experiments described above the differences of the genotypes involved were no doubt very complex despite the close relationship of some of the strains. Gustafsson (9) studied a case where there was only one gene difference. He found a pronounced "cooperation" when the offspring of the erectoides monohybrid barley were considered. A mixture of one-fourth AABB, one-half AaBB, and one-fourth aaBB produced four per cent more than the normal homozygote AABB, despite the fact that AaBB is by three per cent inferior and aaBB by 14 per cent inferior to AABB genotype of the same offspring.

A negative attitude towards improvement by means of blending characterized the conclusions of Frankel (8) who in careful experiments analyzed the yield properties of mixtures and pure strains. "In all nine trials the yield of the blends were closely similar to expectations, only in two out of the nine varieties was there any indication of an increased yield due to blending."

MATERIALS

Twenty-six advanced lines, considered as potential varieties, were included in the study. These are listed in Table 1. All of the kinds may be presumed to have been more or less adapted to the area. Each kind was represented by three entries: an original strain, a purified bulk, and a pure line. These represented different degrees of variability.

Table 1. Kinds included in the study with their respective CI or selection numbers.

Variety or cross	CI No.	Selection No.
Turkey	1558	
Comanche	11673	
Wichita	11952	
RedChief	12109	
Ponca	12128	
Triumph	12132	
Kiowa	12133	
Marquillo-Oro X Oro-Tenmarq	12406	
Blue Jacket	12502	
Pawnee selection	12707	
Kanking	12719	
Mediterranean-Hope X Pawnee[2]	12800	
Early Blackhull-Tenmarq X Oro Mediterranean-Comanche	12871	
Mediterranean-Hope-Pawnee X Oro-Illinoi No. 1-Comanche	12872	
Mediterranean-Hope X Pawnee[2]	12873	
Mediterranean-Hope X Pawnee[3]	13112	
Ivcl-Comanche X Pawnee-Comanche		472941
Mediterranean-Hope-Pawnee		49369
Mediterranean-Pawnee X Oro-Illinoi No. 1-Comanche		49413
Kawvale-Mediterranean-Tenmarq X Mediterranean-Hope-Pawnee		49444
Kawvale-Mediterranean-Tenmarq X Oro-Illinoi No. 1-Comanche		50234
Kawvale-Mediterranean-Tenmarq X Oro-Illinoi-Comanche		50238
Mediterranean-Hope-Pawnee X Oro-Illinoi No. 1-Comanche		50275
Mediterranean-Hope X Pawnee[3]		51322
Mediterranean-Hope X Pawnee[3]		51324
Mediterranean-Hope X Pawnee[3]		51335

METHODS

Experimental Design and Measurements

A split-plot design was employed. The varieties, hereafter referred to as kinds, were the main treatments, and the entries, i.e., original strain, purified bulk, and pure line stocks from each kind, were the sub-treatments. The sub-plot treatments were randomly allotted to units within each whole plot, a different randomization being used within each main plot. The whole plots were randomized in a complete block design. Three replicates were planted at each location, Manhattan and Hutchinson, yearly for a period of three years, 1956 to 1958, inclusive.

Each sub-plot consisted of four rows, all planted to approximately ten feet and trimmed to eight feet prior to harvest. The two center rows of each sub-plot were harvested for yield.

Plant height was measured as the average distance in inches from the ground to the tip of the spike, excluding awns, of three plants picked at random, one at one end of the sub-plot, one in the middle, and the third at the other end.

Maturity was recorded as the date in May when one-half the heads had started to bloom. This is considered somewhat more reliable in indicating the earliness of a strain than the emergence of the head from the boot.

Test weight was determined in pounds per bushel, using a standard half-pint kettle. However, in 1956 the amount of grain was not sufficient to fill the half-pint kettle, and a small tube about 25 cc was used as a standard volume, and its weight full of grain recorded in grams was taken as a measure of test weight.

Statistical Analysis

Statistical analysis of the data was performed separately for each experiment, using the methods of Snedecor (27) and Cochran and Cox (5).

The following assumptions have been made:

1. The productivity levels of the plots assigned to any entry or variety are independent of those assigned to any other.

2. The estimates of individual plot yields, or other character being considered, are normally distributed about the "true" value.

3. The distribution of estimates for every plot has the same variance.

In cases where it was believed possible to secure more information from a combined analysis of two or more years' results, the general methods prescribed by Cochran and Cox (5) and Yates and Cochran (30) were followed. Before the combined analysis was made, a test was performed to determine whether or not the error variances of the experiments being combined could be considered homogeneous. When only two variances were involved, Snedecor's test in which F is calculated as the quotient of the larger variance divided by the smaller was used. When three experiments were to be combined, Bartlett's test of homogeneity was employed to determine the homogeneity of the error variances involved.

EXPERIMENTAL RESULTS

Yield Data

Manhattan. The yield data for the trials at Manhattan in the years 1956, 1957, and 1958 were analyzed separately, analysis of variance being summarized in Table 2.

Table 2. Analysis of variance of yield for the wheat kinds grown at Manhattan, Kansas, 1956 to 1958.

Source of variation	D.F.	Mean square		
		1956	1957	1958
Replicates	2	38,194	65,427	57,172
Kinds	25	3,622**	16,800**	12,881**
Error (a)	50	3,646	3,540	4,708
Main plots	77			
Entries	2	596	1,383	451
Entries X kinds	50	278	1,372	2,852
Error (b)	104	418	1,999	2,099
Total	233			

**Highly significant.

In all three years the F value of kinds exceeded the one per cent level, indicating a highly significant difference between varieties and strains included in the experiment. On the other hand, neither the F value for entries nor interaction of entries and kinds reached the 0.05 level of probability, thus indicating that the entries as groups of original strains, purified bulks, and pure lines were not significantly different, and that there was no significant difference between entries of any one variety.

Hutchinson. Analysis of variance of the yield data from the trials conducted at Hutchinson in the years 1956, 1957, and 1958 are presented in Table 3.

Table 3. Analysis of variance of yield for the wheat kinds grown at Hutchinson, Kansas, 1956 to 1958.

Source of variation	D.F.	Mean square		
		1956	1957	1958
Replicates	2	12,816	8,804	17,848
Kinds	25	4,442**	18,000**	7,869**
Error (a)	50	1,162	3,330	1,216
Main plots	77			
Entries	2	1,501**	3,080**	288
Entries X kinds	50	508**	3,891**	318
Error (b)	104	59.5	248	687
Total	233			

** Highly significant.

Here again in all three trials the kinds had shown highly significant differences. The analysis of yield data for 1958 at Hutchinson showed results that were in agreement with those obtained for experiments conducted at Manhattan, i.e., no significant differences between entries as groups, nor was there a significant kind X entries interaction. However, in contrast to those results, significant differences were found between entries as groups of original strains, purified bulk, and pure lines. Likewise, significant kind X entry interaction was found, indicating that for different kinds different entries might have performed best.

The means for entries as groups were calculated for each year as follows:

Entry	Mean yield of entry in grams	
	1956	1957
Original strain	186	296
Purified bulk	188	294
Pure line	177	284

The L.S.D. for entries was calculated and found to be equal to 8 and 9.2 grams for 1956 and 1957, respectively. This indicates clearly that on the average pure lines had yielded in 1956 and 1957 significantly less than the other two entries.

Since the kind X entry interaction was found significant, the L.S.D. for entries within any one variety was calculated and the mean for original strains, purified bulks, and pure lines for each variety was also calculated. Varieties that showed differences greater than the L.S.D. between the means of their original strain, purified bulk, and pure line are listed in Table 4, with the entry that was significantly different from the other two indicated.

Combined Data. From previous yield trials it was known that the variety X year interaction usually is significant in wheat variety trials conducted in the Great Plains, Salmon (25). However, the following analysis was made to find out if there was a difference in the consistency of the year-to-year performance of the entries, i.e., pure lines, purified bulk, and original strains.

Analysis was made for each entry in each year, from which no further information was secured, but was merely done as a prerequisite of a combined analysis for the data of each entry in the three years of the trial.

Table 4. Kinds that showed significant differences in yield between their entries at Hutchinson, Kansas.

Kind	Means of entries 1956			Means of entries 1957		
	O.S.[1]	P.B.[2]	P.L.[3]	O.S.[1]	P.B.[2]	P.L.[3]
Wichita	205[5]	181	176	295	283	211[4]
Triumph	198	227[5]	207	294	331[5]	281
Kiowa	176	208	232[5]	245	248	284[5]
CI 12871	181	215[5]	189	352	388[5]	344
Comanche	220	210	186[4]	234	254	248
Ponca	151	160	131[4]	267	289	314[5]
CI 13112	162[4]	202	198	302[4]	331	336
50238	146	155	124[4]	285	373[5]	276
51324	155[4]	175	181	228	293[5]	235
49444	167	155	159	267[4]	359	343
CI 12406	225	209	218	249	309[5]	255

[1] Original strain
[2] Purified bulk
[3] Pure line
[4] Significantly lower
[5] Significantly higher

One of the assumptions underlying a combined analysis of variance is that of homoscedasticity, or equal error variance, Eisenhart (6). The exact consequences of failure to meet this assumption and others are not known, Cochran (4). The effect of unequal error variance is considered serious because it disturbs the level of significance and decreases the sensitivity of the F and t tests.

Bartlett's test of homogeneity of variances was applied to error variances of the three years. In each case, i.e., original strains, purified bulk, and pure lines, unadjusted chi square value were found to be equal to 9.31, 10.15, and 10.91 for the entries, respectively. Those values were found to be significant.

Results of a combined analysis, when it is known that the pooled error mean square is made up of heterogeneous experimental errors, must be approached with caution. The analysis of variance for combined three years data for each of the entries at each location is presented in Table 5.

Table 5. Combined analysis of variance of yield for three years (1956 to 1958) at both Manhattan and Hutchinson.

Source of variation	D.F.	Mean square		
		O.S.[1]	P.B.[2]	P.L.[3]
		Manhattan		
Years	2	3,001,172**	3,109,153**	4,053,491**
Replicates within years	6	30,920	32,431	35,249
Kinds	25	4,237**	5,491**	6,499**
Year X kind	50	4,371**	5,462**	9,176**
Error	152	2,001	1,943	2,132
Total	233			

Table 5 (concl.).

Source of variation	D.F.	Mean square		
		O.S.[1]	P.B.[2]	P.L.[3]
		Hutchinson		
Years	2	3,700,607**	3,657,132**	6,061,575**
Replicates within years	6	31,720	30,730	32,040
Kinds	25	3,225**	3,159**	3,216**
Year X kind	50	5,409**	5,250**	7,382**
Error	152	1,443	1,418	1,430
Total	233			

[1] Original strain
[2] Purified bulk
[3] Pure lines
** Highly significant

The estimated mean square for each component in the foregoing analysis is presented as follows, where e= error, K = kind, Y = year, σ = variance, and R = replicate.

Source	$\sigma^2 e$	$\sigma^2 YK$	$\sigma^2 K$	$\sigma^2 R{:}K$	$\sigma^2 Y$
Years	1	3		26	78
Replicates within years	1	3		26	
Kinds	1	3	9		
Kinds X years	1	3			
Error	1				

Thus the actual variance for years would be figured out in the following manner:

$$\sigma^2 Y = \frac{\text{M.S. for years - M.S. for replicates within years}}{78}$$

The year variances calculated in the method described above are given in Table 6.

Table 6. The year variances of yield for the three entries at Manhattan and Hutchinson, Kansas.

Entry	Year variance	
	Hutchinson	Manhattan
Original strain	47,037	41,025
Purified bulk	46,492	42,192
Pure line	77,186	59,413

Inspection of Table 6 shows that the pure lines as a group have shown a change in yield, from one year to the other, considerably larger than the other two groups. However, although difference in variance between the pure lines and the other two groups is large, no significance was found when the F test was applied. Due to the low number of degrees of freedom associated with the year variance, only very large differences would be expected to show significance.

It is also interesting to note that examination of Table 5 showed a larger year X kind interaction for pure lines than for either the original strain or the purified bulk. This would mean that more shifting had occurred in the relative position of the varieties in the pure line group than in the other two groups, or, in other words, the original strains and purified bulks tend on the average to be more stable than the pure lines.

In order to classify the varieties according to their yield, a combined analysis of the yield data for the three-year period at both locations was made. It was noted that the variety X location interaction was not significant. But both the variety X year interaction and the variety X location X year second order interaction were significant. This indicated that varieties responded differently under different environments, but there were no consistent location effects. The second order interaction was used as the error term to calculate the L.S.D. which was found to be 31 grams. The varieties are arrayed according to their mean yield in Table 7.

Table 7. Mean yield for kinds at Manhattan and Hutchinson, Kansas, 1956 to 1958.

Rank	Kind	Mean	Rank	Kind	Mean
1	Kiowa	317	14	Comanche	292
2	CI 12873	312	15=	CI 12406	291
3	CI 12707	310	15=	CI 12800	291
4	472941	309	17	50238	284
5=	CI 12871	307	18	12872	283
5=	49413	307	19	51324	281
5=	51335	307	20	51322	279
8	50275	305	21	Blue Jacket	270
9	Kanking	303	22	Ponca	260
10	Triumph	301	23	RedChief	249
11	CI 13112	298	24	50234	238
12	49369	297	25	Wichita	232
13	49444	293	26	Turkey	222

Test Weight Data

Manhattan. The test weight was recorded in 1956 as the weight in grams of the grain that filled a tube about 25 cc. In 1957 and 1958 a standard half-pint kettle was used and test weight was recorded as pounds per bushel. Analysis of variance for the three years data is summarized in Table 8.

Table 8. Analysis of variance of test weight data at Manhattan, Kansas, 1956 to 1958.

Source of variation	D.F.	Mean square		
		1956	1957	1958
Replicates	2	8.29	10.72	12.64
Kinds	25	19.39**	28.65**	30.92**
Error (a)	50	1.34	0.69	0.94
Main plots	77			
Entries	2	0.269**	0.241*	0.194
Entries X kind	50	0.50 **	0.663**	0.29
Error (b)	104	0.11	0.164	0.21
Total	233			

* Significant
** Highly significant

Hutchinson. Test weight was recorded in 1956 and 1957 as the weight in grams of a tube full of grain (about 25 cc), for all the entries concerned. However, sufficient grain was available in 1958 to use a standard half-pint kettle to measure the test weight in pounds per bushel. Analyses of data obtained in the three years are presented in Table 9.

It was found that at both locations in all three years the differences between the kinds were always highly significant, a fact to be expected because the varieties included in the experiment represented a wide range of test weight values. However, in considering the entries as groups of original strain, purified bulks, and pure lines, results obtained at both locations in the years 1956 and 1957 showed considerable agreement, while results obtained at both locations in 1958 were not in agreement with those of the preceding two years.

Table 9. Analyses of variance of test weight data at Hutchinson, Kansas, 1956 to 1958.

Source of variation	D.F.	Mean square		
		1956	1957	1958
Replicates	2	7.16	3.31	4.27
Kinds	25	20.50**	7.62**	5.43**
Error (a)	50	2.11	0.98	0.85
Main plots	77			
Entries	2	0.291**	0.210*	0.159
Entries X kind	50	0.731**	0.426*	0.282
Error (b)	104	0.123	0.132	0.184
Total	233			

* Significant
** Highly significant

In the results obtained in 1956 and 1957, a significant difference was always found between the entries. The means of entries for each year at each location were arrayed as shown in Table 10, along with the corresponding L.S.D. values.

Table 10. Mean test weight for entries at Manhattan and Hutchinson, Kansas, 1956 and 1957.

Location	Year	Entry mean test weight			L.S.D.
		Original strain	Purified bulk	Pure line	
Manhattan	1956	24.7	24.9	24.6	0.19 gm
	1957	56.9	57.4	56.9	0.35 lb/bu
Hutchinson	1956	26.1	26.4	26.0	0.26 gm
	1957	22.8	23.1	22.7	0.25 gm

In both years the purified bulks as a group showed higher test weight than either the original strain or the pure line stocks. However, although this was the general tendency, the significance of the entry X kind interaction indicated that this was not always the case when considering individual kinds. By arraying the means for each entry in each year for all the varieties included in the study, it was possible to pick out the entries which were significantly better for some varieties and those which showed considerable consistency in the two years.

Inspection of Tables 8 and 9 showed significant differences between the varieties in 1958. But on the other hand, both F values for entries as groups and for entry X kind interaction were not significant. This means that in 1958 there was no difference between the entries as groups of pure lines, purified bulk, and original strain, or between the entries within any one variety.

Table 11. Entries that showed consistent superiority or inferiority with regard to test weight.

Kind	Entry		
	Original strain	Purified bulk	Pure line
50234	Superior		
51324		Superior	
Turkey			Inferior
CI 12800	Superior		
49369			Inferior
Wichita		Superior	
Ponca			Superior

Table 11 shows the entry for each variety which had shown consistent difference in test weight from the other two entries within the same variety. Such consistent differences were only found in seven varieties and even then the differences are so small that it is doubted if they would be of any practical value, all of them being in the range of 1.2 to 0.6 pound per bushel.

In order to classify the varieties according to their test weight, the data which were recorded as weight in grams of grain that filled a glass tube, were transformed into pounds per bushel. The Bartlettes' test showed that the error variances for the experiments in all three years could be considered homogeneous. The combined analysis showed that there was difference between the years 1956, 1957, and 1958 as far as test weight was concerned, and that the kinds did not react significantly different from one year to the other. The means of test weight of the varieties for the three-year period were calculated and are arranged in Table 12.

Table 12. Arrayed mean test weight for the kinds at Manhattan and Hutchinson, Kansas, 1956 to 1958.

Rank	Kind	Mean lb/bu	Rank	Kind	Mean lb/bu
1=	Kanking	60.5	8=	Triumph	57.5
1=	CI 12871	60.5	15=	Ponca	57.0
3=	RedChief	59.5	15=	50275	57.0
3=	Blue Jacket	59.5	17	50238	56.5
5	50234	58.5	18=	51335	56.0
6=	CI 12707	58.0	18=	CI 12873	56.0
6=	47941	58.0	18=	49444	56.0
8=	49369	57.5	21=	Comanche	55.5
8=	Kiowa	57.5	21=	CI 12800	55.5
8=	CI 12872	57.5	21=	51324	55.5
8=	Wichita	57.5	21=	51322	55.5
8=	CI 12406	57.5	21=	CI 13112	55.5
8=	49413	57.5	26	Turkey	53.5

The L.S.D. calculated on the basis of the pooled error variance was equal to 3.1 pounds per bushel.

Plant Height

The only available plant height data were those recorded at Hutchinson in 1956 and at Manhattan in 1958. These were analyzed separately. Pertinent parts of each analysis are included in Table 13.

Table 13. Analysis of variance of plant height at Hutchinson in 1956 and at Manhattan in 1958.

Source of variation	D.F.	Mean square	
		Hutchinson	Manhattan
Replicates	2	123.67	106.50
Kinds	25	6.74**	15.28**
Error (a)	50	2.09	2.16
Main plots	77		
Entry	2	1.30	1.50
Entry X kind	50	0.51	0.84*
Error (b)	104	0.67	0.53
Total	233		

* Significant
** Highly significant

The F values for kinds were significant in the two years, indicating a significant difference between the varieties. The only other significant value obtained was that of the entry X kind interaction for Manhattan data, indicating that different entries were greater in height than others within the same variety. The L.S.D. was calculated using "error (b)" as the error term. Table 14 lists the varieties where differences were detected between the entries within the same variety.

Table 14. Mean height of entries for each variety that showed interaction at Manhattan in 1958.

Kind	Entry mean		
	Original strain	Purified bulk	Pure line
Comanche	40.6**	41.1	41.6
RedChief	44.6	44.3	43.0**
Ponca	40.0	39.0**	40.0
472941	42.3	42.3	41.0**
49413	42.3	43.3*	42.3
51324	38.3*	39.3	40.0

* Significantly taller
** Significantly shorter

Date of Flowering

Notes on the date of flowering were only taken at Manhattan in 1957 and 1958. Summarized analyses of variance for the two seasons are presented in Table 15.

Table 15. Analyses of variance of the date of flowering at Manhattan in 1957 and 1958.

Source of variation	D.F.	Mean square	
		1957	1958
Replicates	2	32.49	22.20
Kinds	25	56.14**	70.56**
Error (a)	50	2.14	1.43
Main plots	77		
Entry	2	0.090	0.055
Entry X kind	50	0.035	0.015
Error (b)	104	0.211	0.113
Total	233		

** Highly significant

A highly significant difference in flowering date between kinds was observed each year. On the other hand, no significant difference was found between the entries as groups of original strains, purified bulks, and pure lines. Similarly, no significant entry X kind interaction was found in any of the two years under consideration. This means that for any one variety no significant difference was detected between the original strain, purified bulk, and pure line, or, in other words, they could be considered as samples from the same population as far as date of flowering is concerned.

Lodging Percentage

Notes on lodging were taken only at Manhattan in 1958. Analysis of variance of the data is presented in Table 16.

Table 16. Analysis of variance of lodging data at Manhattan, Kansas, in 1958.

Source of variation	D.F.	S.S.	M.S.	F
Replicates	2	4,256	2,128	
Kinds	25	28,885	1,155	2.028**
Error (a)	50	28,477	569.5	
Main plots	77	61,618		
Entry	2	485.6	242.8	
Entry X kind	50	3,347.7	669.5	
Error (b)	104	9,383.4	902.2	
Total	233	74,835.7		

** Highly significant

Data in Table 16 show that significant difference was found between the varieties included in the experiment. But on the other hand, neither the entries as groups of original strains, purified bulks, and pure lines, nor the interaction between entries and kinds showed any significance. This means that within any one variety there is no difference between pure lines, purified bulks, and original strain as far as lodging percentage is concerned.

DISCUSSION

The varieties included in the study were advanced lines being considered as potential varieties, each of which may be presumed to have been more or less well adapted. The three entries within any variety may be assumed to represent different degrees of variability. The performance history of the varieties was known and from previous yield trials it was also known that the variety X year interaction usually is significant in the wheat variety trials in the Great Plains, Salmon (25).

The experiments reported do not offer a direct clue that would throw additional light on the possibility of competition for mutual advantage suggested by Richmond (22), or cooperation between genotypes suggested by Gustafson (9), as the composites did not show consistent superiority over pure lines. On the other hand, one might argue that the biotypes that made up the composites were at the disadvantage of being inferior to the pure lines, as the latter were actually selections from the former, and might have actually "cooperated" to reach the level of the potentially superior pure lines. Perhaps a greater expression for total yield would have been obtained had the components of the mixtures been selected for equal performance with the pure lines.

Since the original strains and purified bulks as groups gave higher yields than the pure lines at Hutchinson in 1956 and 1957, two seasons characterized by shortage of water, it can be inferred that mixtures tend to do better than pure lines under adverse conditions. This is not unexpected, as the differences in physiological requirement and growth rhythm of the component biotypes may create better conditions for the individual plant in a composite than in a pure population, where the requirements of all members are closely similar as well as simultaneous.

It is worth noting, however, that the composites as groups did not give lower yields than the pure lines under any of the conditions encountered in the experiment. In fact, the comparison of the year of the entries as groups showed a distinct tendency of composites, i.e., original strain and purified bulk, towards more consistent year-to-year behavior than in the case of the pure lines. By comparing the year variances for the entries as groups, it would be noticed that it was about 39 per cent and 30 per cent lower at Hutchinson and Manhattan, respectively, for the composites as compared to the pure lines. The reduction may be even more important than indicated by the percentages since the variety X year interaction was also greater for pure lines than the other two groups. It is also probable that the buffering effect of certain composites would have been more apparent had the experiment been of larger duration.

Insofar as the varieties included in the study are representative of the agricultural varieties of wheat in Kansas, and the three seasons are a representative sample, composites as groups seem to yield better under adverse conditions and to show more year-to-year consistency as far as yield is concerned.

A number of experimenters have discussed in some detail the analysis of data from experiments conducted simultaneously at a number of places, and much less extensively those conducted at the same place for a number of years. The problems are basically the same except for one important difference. A significant locality X variety interaction means merely that practical recommendations may be different for different localities. Horner and Frey (14) found that they could reduce this interaction considerably by decreasing the areas of recommendation. Technically, the same is true for season X variety interaction, but it is not a practical solution. Farmers want to know what varieties are most likely to be best for a period of years. It is generally considered that if statistical methods are to be used for interpreting such data, the season X variety interaction should generally be used as the error term rather than residual error. This seems to be important in evaluation of varieties, especially in places like Kansas where climatic conditions vary considerably from one year to the other. It is to maintain some stability of yield over the ever-changing climatic conditions that the use of composites is being advocated rather than the maintenance of purity.

To meet the changes in environment imposed upon plant growth by the unavoidable variation of weather, soil, and management, the plant breeder has the choice among four alternatives. He may aim at producing a variety of great adaptability, an all-round variety to suit the requirement of a larger district. He may produce varieties suitable for more narrowly confined conditions, thus aiming at a higher degree of specialization, provided that climatic conditions keep relatively constant within these areas of adaptation. He may advocate the cultivation of a number of more or less similar varieties which would tend to level out the uncertainties resulting from seasonal fluctuation in the return of any one variety. Or, lastly, he may advocate the sowing of varieties in blend, a suggestion which would be hard to conceive under our present concepts of purity.

The use of mixed cultures embracing different species is an old practice and the unconscious cultivation of varietal mixtures of one species is equally ancient. The question may be asked whether there is not a logical extension of the principle of diversification from the inter-varietal to the intra-varietal. In other words, can a single variety be developed with "built-in" protection? There seem to have been few attempts to develop such a variety. However, the data available from various studies with mixtures may be extended to bear on this subject.

A broad adaptation base may be provided by the maintenance of a certain amount of heterozygosity, or heterogeneity, or both. In wheat, which is a self-fertilized crop, there is a definite inbreeding during the process of developing a variety. Under such conditions the preservation of broad adaptation can be accomplished by propagating varieties as mixtures of biotypes.

Rosen's (24) proposal of using mixed populations from a cross and not breeding for uniformity has merit from a theoretical viewpoint and is certainly a less expensive procedure. But it may be questioned whether varietal uniformity should be disregarded in wheat breeding. The concept of uniformity is now reflected in the thinking at all levels of crop improvement, in the pride the seedsman takes in his product, and the grower in his crop. Schlehuber (26) pointed out the importance of uniformity in a survey of methods of small grain seed production in the United States, and it seems to be written everywhere into variety and crop standards. On the other hand, a mixed population would be expected on theoretical grounds to possess the characteristics of longer varietal life, greater stability of production, broader adaptation to environment, and greater protection against disease.

Admittedly, varietal improvement must start from primary selection and the use of progeny rows. It is hoped that some method of breeding might be devised that would incorporate the advantages of selfing but not reduce plasticity. Assuming that a particular economic character in a population is controlled by a large number of minor genes, the chance of choosing a single plant and of breeding a line from it homozygous for all of these genes is obviously remote. Still more remote is the chance of selecting a plant carrying all the gene complexes for all the traits desired. If a large number of progeny rows are grown and the rows showing the maximum improvement in the desired characters are selected, then it is likely that selected progenies all will carry a large number of these favorable genes, though not necessarily the same ones. Equally these selected progenies will carry a number of physiologically less favorable genes, again not necessarily the same ones in each line. The difference in both favorable and unfavorable genes among various biotypes constituting a composite variety gives the buffering effect expected from such mixtures.

As has been suggested by Jensen (15), it would be possible to produce a satisfactory multiline variety through a blend of multiple pure lines. Through a knowledge of the characteristics of the individual lines and the performance data gathered in the usual way, the plant breeder would be able to blend reasonably compatible lines in proper proportions. Such a variety should be uniform for important characteristics like disease resistance or resistance to winter injury, and reasonably uniform with regard to maturity and height. Differences in such characteristic as panicle color should not necessarily detract from performance, but may detract from visual appearance and farmer acceptance. On the other hand, if such varieties perform better than the "pure" lines, farmers may readily accept such new "mixed" varieties.

SUMMARY

A series of split-plot experiments were conducted to compare the performance of pure lines, purified bulks, and original strains of 26 promising advanced lines of winter wheat. The series consisted of three replications at Manhattan and at Hutchinson, Kansas for three years, 1956 to 1958, inclusive.

The yields of the varieties differed significantly in each test and were also found to be significantly different on the basis of combined data. At Hutchinson in 1956 and 1957, the pure lines as a group yielded significantly lower than the other two groups; however, no such difference was found at Manhattan. A combined analysis of the three years for each group of entries separately had shown more consistent year-to-year performance in the case of purified bulks and original strain than in the case or pure lines. This difference in consistency of performance was detected at both locations, but it was more evident at Hutchinson than it was at Manhattan.

Significant differences were found between the test weights of kinds included in the study. The purified bulks as a group gave a significantly higher test weight than the other two groups of entries. This difference was found in 1956 and 1957 at both locations, but no such differences were found in 1958.

Varieties showed significant differences in height, date of flowering, and lodging percentage, but no consistent differences were found between the entries as groups with respect to those characteristics.

No consistent superiority of any of the three entries was found. Still the value of original strains and purified bulks in providing more flexibility of response to environment was recognized; hence the use of multiline varieties was advocated for areas where the conditions vary considerably from one season to the other.

ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude to those persons who made the completion of this study possible. Suggestion of the problem, advice, and constructive criticism on this manuscript have been offered by Dr. E. G. Heyne, major instructor. The author wishes also to acknowledge the aid of Dr. H. C. Fryer and Dr. S. Wearden, statisticians at Kansas State University, for advice in analyzing and interpreting the data.

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EVALUATION OF PURE LINES, PURIFIED BULKS, AND THE ORIGINAL WHEAT STRAIN IN PERFORMANCE TRIALS

by

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B. S., University of Khartoum, Sudan, 1957

AN ABSTRACT OF
A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
OF AGRICULTURE AND APPLIED SCIENCE

1959

Many workers have reported the superiority of interspecific or intervarietal mixtures in agricultural crops as compared to their corresponding pure stands. The question may then be asked whether there is a logical extension of the principle of diversification to the intravarietal level. As has been suggested by different workers, a multiline variety would be expected, on a theoretical basis, to possess the characteristics of longer varietal life, broader adaptation base, greater protection against disease, and greater stability in production, especially under hazardous conditions.

It is the purpose of this paper to report the results of an experiment designed to compare the performance of pure lines, purified bulks, and original strains of 26 promising advanced lines of winter wheat.

A split-plot design was employed, the lines, referred to as kinds, being the main treatments, and the entries for each kind, i.e., pure lines, purified bulk, and original strain, the subtreatments. The experiment consisted of three replicates at Manhattan and also at Hutchinson, Kansas, and was repeated for three years, 1956 to 1958, inclusive.

Yield in grams per 16-square-foot plot, test weight in pounds per bushel, or in grams per 25 cc when grain was insufficient to use a half-pint kettle, plant height in inches, date in May on which the half-bloom stage was reached, and lodging as a percentage were recorded during the study.

Each experiment was analyzed separately, and combined analyses done when it was thought that more information could be secured.

The yields of the kinds differed significantly in each test and were also found to be significantly different on the basis of combined data. At Hutchinson, in 1956 and 1957, the pure lines as a group yielded significantly lower than the other two groups. However, no such difference was detected at Manhattan. On the basis of combined three years' data for each group of entries separately, it was evident that the yield of original strains and purified bulks was much more consistent than that of pure lines. Significant differences were also found between the test weights of the kinds included in the study. The purified bulks as a group gave a significantly higher test weight than the other two groups at both locations in 1956 and 1957, but no such difference was found in 1958. Regarding height, date of maturity, and lodging percentage, significant differences were found between the kinds, but no consistent differences were found between the entries as groups.

Bearing in mind that the 1958 season was more favorable than the other two, one may infer from the results that composites tend to do better, under unfavorable conditions, than the pure lines. It is worth noting that under no conditions encountered in this series of experiments, did the pure lines show superiority over the other two groups. Considering the results from combined analyses, it is again apparent that the composites tend to show more consistent year-to-year performance than the pure lines.

On the basis of the observed stability of original strains and purified bulks as compared to the pure lines, and on the assumption that the chance for maximum production is subordinated to the principle of stability, the use of multiline varieties is advocated for places where the year-to-year variation in environmental conditions is considerable.

As had been suggested, through a knowledge of the characteristics of the individual component lines, and with performance data collected in the normal way, the plant breeder should be able to build compatible lines into a composite variety.