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TECHNIQUES OF SELECTION FOR YIELD IN WHEAT

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SUMMARY

Nine selectors, including breeders, technicians and others, selecting at a 25% level, were not able to choose the highest yielding lines of wheat. The average of the choices of most selectors was only slightly better than the average of all lines in the test. Three breeders selected many lines in common with each other and in common in the same material grown and selected at two locations. It has been previously shown that moving-mean analysis is more effective in correcting for error than using a control every third plot. The use of moving-mean analysis requires the harvesting of every plot, thus making visual selection of little value. With the use of a table and a heritability figure for a test, it was shown that the intensity of selection necessary to identify seven to nine out of the ten highest yielding lines can be calculated.

The primary objective of many wheat-breeding programs is to increase the yield potential of a particular quality class of wheat. SHEBESKI (1967) pointed out that this objective can only be met through the use of very large populations which are subjected to yield testing in early generations. Early and repeated yield tests of large populations often leads to an overtaxing of the limited resources available to most breeders in North America. In this paper we suggest methods of utilizing these limited resources in the most efficient manner.

Perhaps the most important factor restricting the choice of methods for yield-testing early generations is the small quantity of seed. The testing of F_3 lines is limited by the seed produced by a single F_2 plant. Often this quantity is sufficient for only two or three multiple-row plots. The resulting low level of replication leads to low heritability of yield estimates, particularly in tests of very large numbers of lines. SHEBESKI (1967) proposed a scheme employing a control variety in every third plot to reduce the effects of soil variability and increase the heritability of yield estimates. After evaluating this system BRIGGS and SHEBESKI (1968) concluded ". . . frequent controls are essential for efficient selection for yield in hybrid nurseries."

This system has been questioned on both theoretical and practical grounds. BAKER and McKENZIE (1967) concluded that there is no advantage to the use of control plots unless Smith's (1938) coefficient of soil heterogeneity is less than 0.5, and there is no more than an equal chance of its being less than 0.5 in any given experiment. KNOTT (1972) tested the value of frequently repeated control plots and an adjustment employing the moving mean of seven experimental plots. The data gave no clear indication of which adjustment was superior, though both adjustments were superior to no adjustment. Conversely, Baker and McKenzie found decreases in precision in some cases and in no case was the increase in precision sufficient to justify the extra resources required for the control plots.

TOWNLEY-SMITH and HURD (1973) compared the efficiencies of adjustments employing repeated controls and those employing moving means of varying numbers of experimental plots. The use of repeated control plots gave reductions in experimental error of 1.2 to 34.2% in three of five trials, while in the other two trials no reductions were found. Reductions in error mean square were obtained in all trials using moving means, and in each case the reduction was greater than that obtained with control plots. Clearly, the moving mean of adjacent hybrid plots gives superior control of the experimental error. The control plot scheme also has the disadvantage that it requires up to 33% more plots to test a set number of lines.

In North America the population sizes are likely to be limited by the number of plots which can be harvested. Visual selection for yielding ability offers a possible means of reducing the number of plots harvested. BRIGGS and SHEBESKI (1970) concluded that visual selection intensities must be low in order that the highest yielding families be included in the selected portion. Similar results were obtained from studies by HANSON *et al.* (1962); McKENZIE and LAMBERT (1961); and BOYCE *et al.* (1947).

Table 1. Number of plots selected from each yield decile and the mean of the selected sample as a percentage of the population mean

Yield decile	Selector								
	1	2	3	4	5	6	7	8	9
1	2	6	2	5	2	2	3	4	2
2	5	7	5	3	5	4	4	4	5
3	8	6	8	4	7	6	7	5	6
4	8	7	5	5	6	3	1	3	4
5	7	8	8	5	6	6	4	2	6
6	10	10	8	2	6	7	3	8	9
7	7	8	9	4	8	4	8	6	7
8	8	7	9	7	8	8	2	4	5
9	5	9	3	7	5	6	2	12	6
10	5	5	5	11	10	5	7	2	4
Total	65	73	62	53	63	51	41	50	54
Sample mean	101.7	100.5	101.2	105.5	103.6	103.2	102.5	103.5	101.9

A replicated trial of 251 hybrid lines was grown at both Swift Current and Regina in 1971. The cultivar Neepawa was planted in every third plot to facilitate selections. Prior to harvest nine selectors--three wheat breeders (selectors 1 to 3), two technicians (selectors 4 and 5) and four other researchers (selectors 6 to 9)--selected the highest yielding 25% of the hybrid lines at Swift Current. At Regina selections were made by seven selectors, including selectors 1, 2, 4 and 8 from Swift Current. In all cases at Swift Current the lines selected covered the complete yield range of this population (Table 1). Although the mean of each selector's selections was greater than the population mean, many of the highest yielding lines were not selected by any of the selectors. Similar results were obtained at Regina. Obviously a greater number of lines must be selected if one is to include all the high-yielding lines. This agrees with the other researchers. It is interesting to note that the selections of the three wheat breeders had the lowest yield, while those of the two technicians had the highest.

Table 2. Concurrence between selectors expressed as the rate of the actual concurrence/expected concurrence

	Selector							
	2	3	4	5	6	7	8	9
1	2.54	2.93	0.86	2.05	2.27	0.66	0.46	1.86
2		2.50	1.21	1.83	1.82	0.76	0.96	1.59
3			0.90	2.15	2.22	0.59	0.32	1.80
4				1.38	0.91	1.13	1.21	1.12
5					1.77	0.86	0.71	1.74
6						0.96	0.79	2.28
7							1.59	0.91
8								1.21

Table 2 shows the concurrence of the selections at Swift Current. The figures presented are the ratio of the actual concurrence between selections to the concurrence expected with random selections - i.e., a value of two indicates that the selectors concurred on twice as many lines as would be expected at random. Since most selectors selected approximately one-quarter of the lines, this ratio can vary from 0.0 (no concurrence) to approximately 4.0 (complete concurrence). The three wheat breeders had the highest concurrence, indicating that they showed the same strong biases for such characters as kernel type, straw strength, and uniformity of maturity, which had no relation to yield. Similarly the concurrence among selections made by the same selector at different locations was high, particularly for the wheat breeders (Table 3).

Table 3. Concurrence between selections made at Swift Current and Regina, expressed as the ratio: actual concurrence/expected concurrence

		Regina selections			
		Selector			
	Selector	1	3	4	8
Swift Current Selections	1	2.33	2.59	0.23	1.33
	3	2.14	2.47	0.42	1.59
	4	0.85	1.02	1.84	0.91
	8	0.76	0.47	1.55	1.07

Visual selection for yield cannot be used in conjunction with moving mean corrections, but could be of use where repeated controls are used to reduce the variability in large nurseries. However, visual selection intensities must be low, and TOWNLEY-SMITH and HURD (1973) obtained optimum adjustments when four to six control plots were used to adjust each hybrid plot yield. Thus if 40 to 50% of the lines and all the control plots are harvested, the number of plots harvested approximates the number harvested where control plots are not used and all plots are harvested. Therefore we suggest the use of moving means to adjust plot yields and the harvesting of all plots.

The breeder is also faced with the problem of deciding what proportion of the lines he should select on the basis of his yield tests. According to quantitative genetic theory, response to selection can be predicted by the formula $R = ih\sigma_g$, where i is the selection intensity (difference between phenotypic means of selected and unselected populations in phenotypic standard deviations), h is the square root of the heritability of genotype means (correlations between mean phenotypic and genotypic values), and σ_g is the genotypic standard deviation (a constant for any particular cross or population). If a breeder can grow only P plots, he can sample P genotypes if he grows one plot of each or P/2 genotypes if he grows two plots of each. Selecting S genotypes will give a certain selection intensity from P genotypes and a somewhat reduced selection intensity from P/2 genotypes. Using the properties of the normal distribution, BAKER (personal communication) calculated the optimum number of replicates to use for various combinations of S/P (the number of genotypes selected/total number of plots grown) and h^2 (heritability expressed on a single-plot basis). These are presented in Table 4. It can be seen from this table that the proportion of

Table 4. Number of plots of each genotype required for maximum response to selection

	Heritability (Single Plot Basis)								
S/P*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
.0025	15	9	6	4	3	2	2	1	1
.005	12	7	5	4	3	2	1	1	1
.0075	10	6	4	3	2	2	1	1	1
.01	9	6	4	3	2	2	1	1	1
.015	7	5	3	3	2	2	1	1	1
.02	6	4	3	2	2	1	1	1	1
.03	5	3	3	2	2	1	1	1	1
.04	4	3	2	2	1	1	1	1	1
.05	3	3	2	2	1	1	1	1	1

*S/P = number of genotypes to be selected/total number of plots to be grown.

selected genotypes must be relatively high if heritability is low and the number of plots is limited by such supply. Selecting as few as five genotypes when growing 2000 plots would require six replicates with a heritability of 0.3. Experimental data from several populations in our breeding program confirm these estimates. For each of two populations a single plot of each of 330 genotypes was grown at three locations in 1971. In 1972 a total of 249 lines from 24 families of one population and 639 lines from 44 families of the other were grown in three replicate trials at two locations. Table 4 indicates that with three replicates and heritability of 0.3, one should select 0.015 genotypes per plot or 15 genotypes for each of these populations. Selection of the best 15 families in 1971 would have included seven and eight of the best ten families in 1972, in the two populations. In another test of 228 genotypes at two locations, selection of 18 genotypes in accordance with Table 4 would have included nine of the ten highest yielding families in 1972. In all three cases selecting one-half as many genotypes would have saved only 2 of the best five families.

In conclusion we feel that in order to breed for increased yield one must yield-test large populations in early generations. All plots have to be harvested. Adjustment using moving means should be used to increase heritability, and relatively large numbers of genotypes should be selected for the next generation of testing. In order to handle the large volume of plots, a high degree of mechanization is required. We also recommend the use of a computer to print field books and plot labels.

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