EVALUATION OF F_3 SELECTION FOR YIELD

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by

Lindsay O'Brien

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LINDSAY O'BRIEN

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ABSTRACT

O'BRIEN, LINDSAY, Ph.D. The University of Manitoba, October, 1977.
Evaluation of F_3 Selection for Yield. Major Professor: L. E. Evans.

Four wheat crosses that involved the cv. Glenlea as a common female parent, were used to evaluate the effectiveness of F_3 selection for yield in its two components, the ability of the yield test to identify high-yielding lines, and the persistence of their yield performance into later generations. Seventy eight random large F_2 plants were evaluated as F_3 lines in a three replicate yield test using three-row x 3 m length plots and a nine replicate hill plot yield test where hill plots of 30 seeds per hill were planted on an approximate 1 m grid. Ten high-yielding and ten low-yielding entries were selected from each cross using the mean of the three-row plot yields and the mean of four replicates of the hill plot yields. F_4 and F_5 bulks and families of F_5 lines were derived from each of the selected F_3 entries, and their performance in a subsequent season in replicated tests of three-row x 3 m length plots used to verify the results of the F_3 yield tests. The replicated F_3 yield tests identified high-yielding lines. There were significant phenotypic correlations (P = 0.01) for each cross between yield performance of F_3 entries in hill plots and three-row plots. The genetic correlations between hill plot and three-row plot performance indicated that the genotypes were performing similarly in the two plot types. Hill plots could be used for early generation testing if seed supply was limited. Hill plots had increased error variation, they required more replications to estimate yield differences between genotypes and they must be hand planted and harvested compared with a totally mechanised operation for three-row plots. The mean performance of the derived F_4 and F_5 bulks and the means of the families of F_5 lines confirmed the yield classification based on F_3 performance in Crosses I and II and in some instances in Crosses III and IV. Crosses I and II were characterised by lower population mean yield than Crosses III and IV, but considerably increased genetic variance compared with Crosses III and IV. Errors of misclassification of yield potential based on F_3 yield performance were detected. The observed responses to selection of the F_4 and F_5 bulks and the F_5 family means were less than the predicted responses probably because the estimates of heritability obtained from the F_3 yield test were biased upwards due to the estimate of genetic variance being confounded with components of variation resulting from genotype x environment and genotype x year interaction effects. The strength of intergeneration correlations between F_3, F_4 and F_5 bulk and F_5 family mean performance were influenced by the yield range and genetic variance in the F_3 yield test. In all four crosses, replication resulted in an improvement in the intergeneration correlations. Genotype x year effects did not seem to be as important as the precision of estimating the yield value of a genotype (i.e. the use of replication). Adjustment of entries in single replicate yield tests to a percentage

of their adjacent control plot failed to improve the intergeneration correlations. The number of F_5 lines that can be evaluated per selected F_5 was shown to be determined by (1) the final objective of the breeding program (2) the variability of response to selection (3) the maximisation of response. Selection of spaced plants from the F_2 and F_4 generation winter nurseries in which the plants were grown in the absence of interplant competition, seemingly did not affect the performance of the randomly derived selections in the F_3 and F_5 yield tests in which there is interplant competition within the plot. The modification of the pedigree breeding system proposed by Shebeski (1967) has been modified to incorporate replicated F_3 and F_5 yield testing.

ERRATA

p35. Table 8. The single degree of freedom comparison for Cross III was significant at the 5% level of probability.

p34. Alteration to text resulting from change in Table 8. Last sentence of paragraph 1 now reads;

'The mean yield of the F_5 bulks derived from high-yielding F_3 lines was significantly higher than the mean of those derived from low-yielding F_3 lines for Crosses I and II (P = 0.01) and Cross III (P = 0.05).'

p60. The new sentence beginning on line 11 should read;

'The adjustment procedure adjusted the F_4 and F_5 yield values such that a negative correlation coefficient resulted. For Cross IV, the correlation between the replicated values was significant, whereas that based on the unreplicated values was not significant. Furthermore, the.....'

p72. The new sentence on line 19 should read;

'The total operating cost, *C*, can be expressed as, ...'

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performance of their progeny in later generations. It is generally agreed that one cannot select high yielding genotypes on the basis of single plant performance. In order to distinguish high yielding genotypes, Shebeski (1967) proposed a method whereby the seed of harvested F_2 plants could be planted as single replicate entries in three-row plot trials with a control plot adjacent to every breeding entry; the control plot serving as a covariate, adjusting for soil heterogeneity. Yields of the breeding entries could be expressed as a percentage of their adjacent control plot.

Briggs and Shebeski (1971) conducted a study using the F_3 nursery design proposed by Shebeski. They reported a significant intergeneration correlation between F_3 and derived F_4 bulk yields, obtained in different seasons, only when they sampled the complete yield range of the F_3 population. De Pauw and Shebeski (1973) reported significant intergeneration rank correlations between yields expressed as a percentage of their adjacent control plot for F_3 lines and F_4 bulks, and F_3 lines and F_5 family means. De Pauw and Shebeski sampled the whole F_3 yield range to derive the F_4 bulks and the upper 30% of the F_3 yield range to derive the F_5 families. Although De Pauw and Shebeski's intergeneration correlations were significant, the F_3 yield values only predicted 34.8 and 31.4% of the total variability in F_4 bulk and F_5 family mean yields respectively. Knott and Kumar (1975) reported significant ($P = 0.01$) F_3 and derived F_5 line intergeneration correlations ($r = 0.29$ and $r = 0.14$ for the two crosses studied) but stated that the correlations were so low that they were of doubtful value. The strength of the intergeneration correlations between F_3 line yield and the yield of derived F_4 bulks, or F_4 lines, or F_5 lines has been used by some researchers (for example, Briggs and Shebeski, 1971; De Pauw and Shebeski, 1973; Knott and Kumar, 1975) to measure the value of F_3 yield testing.

Low intergeneration correlations suggest that F_3 line performance is not a good predictor of performance of derived bulks or lines. A number of factors can effect the expectations of intergeneration correlations. The precision of the yield estimates in each generation affect the correlations. Reduced precision of the estimates are reflected in reduced heritability estimates. The range of the yield values and the genetic variance in each generation are reflected in the heritability estimates for each generation. The yields in different generations can be considered as separate traits within the same genotype. The phenotypic correlation between two traits within the same genotype has been shown to be due to genetic and environmental causes of correlation (Falconer, 1960). Genotype x environment and genotype x year interactions affect the expectations of intergeneration correlations by reducing the genetic correlation. Using the relationship of correlated response-direct response to selection of Falconer (1960), the effects of reduced heritability estimates and genetic correlation on the expectations of intergeneration correlations are evident.

This dissertation reports the results of a study conducted to:

- evaluate two methods of replicated F_3 yield testing, three-row plots and hill plots, for their ability to identify true genetic differences, and to measure response to selection on the basis of yield in three-row plots.
- assess the relative importance of the precision of yield estimates and genotype x environment interactions by comparing intergeneration correlations measured with different amounts of replication in the same or different years.

LITERATURE REVIEW

Early Generation Selection for Yield

Shebeski (1967) and Sneep (1977) have shown that, for a character controlled by many genes (for example yield), a genotype with all the more desirable genes in either the homozygous or heterozygous condition for any given number of genes, occurs with the greatest frequency in the F_2 generation and its frequency decreases rapidly in subsequent generations. They conclude therefore that selection should commence in the earliest possible generation while the genotypes with all the more desirable genes are present at their greatest frequencies.

In the F_2 generation selection is based on single plants. McGinnis and Shebeski (1968) and Knott (1972) reported that visual selection resulted in an increase in the mean of the selected population compared with random selection. McGinnis and Shebeski concluded that selection of well-tillered, vigorous F_2 plants would be advantageous to a breeding program, whereas Knott concluded that the increase due to visual selection was of little use to the plant breeder. The ineffectiveness of single plant selection has been reported by Bell (1963), and Hamblin and Donald (1974) working with barley, MacKey (1963), and De Pauw and Shebeski (1973) working with wheat and Coyne (1968) working with field beans.

Knott (1972) examined the regressions of F_3 line yields on the yield of their parent F_2 plants and found the size of the regressions to be of little plant breeding value. Fasoulus (1973) proposed the honeycomb method for selecting plants in the absence of interplant competition in the early generations of a breeding program. Selected high-yielding F_2 plants gave rise to high-yielding F_3 progeny when yield in both generations was measured using single plants planted in the honeycomb design. Skorda (1973) reported a study in which the seeds of two F_2 families and their parental cultivars were sown in a randomised complete block experiment with six replications at a seeding rate approaching commercial planting density. From each replication (of crosses and parents) the twenty highest yielding F_2 plants (first selection) and the next twenty highest yielding F_2 plants (second selection) were selected and grown in replicated F_3 yield tests. The correlations between F_3 plot and F_2 plant yield for each cross were nonsignificant within both the first and second selections. However, when the two groups of selections were combined within each cross highly significant correlations ($r = 0.848$ and $r = 0.871$) were obtained. Skorda concluded that the selection was effective as the crosses which generated the higher mean and larger genetic variances of F_3 lines were derived from the higher yielding F_2 plants.

Allard (1960) summarised the studies of selection in the F_2 as follows: "The effect of environment on single-plant yields is so large that selection for heritable high yield in the F_2 is virtually futile. On the other hand, effective selection among spaced F_2 plants for disease resistance and other characters of high heritability is frequently possible. Since selection in the F_2 must be based on performance in a single season, effectiveness of selection in that generation for characters moderately subject to seasonal fluctuations (e.g., plant height, maturity date) is often small. The effectiveness of selection among individual plants is therefore seen to be highly sensitive to the magnitude of the heritable variability relative to environmental variability".

The F_3 generation is the earliest possible generation in which plot yield trials can be conducted. A major factor in F_3 yield testing has been the availability of seed. Because of the failure to select for yield on a single plant basis in the F_2, and reports of interplant competition within plots, plant breeders have moved away from the use of F_2 nursery designs that result in the production of large F_2 plants. As a result, the restricted seed quantity produced by the F_2 plants has dictated the design of F_3 yield nurseries. Mostly, small, single replicate plots have been used in F_3 yield testing.

Shebeski (1967) proposed a single replicate nursery design where each entry was planted adjacent to a control plot and the yield of breeding entries expressed as a percentage of their adjacent control plot. The control plot acts as a covariate for adjusting for soil heterogeneity. The covariate adjustment relies upon the premise that the yield of two plots are more likely to agree the closer they are together. Wiebe (1935) and Briggs and Shebeski (1968) reported significant correlations between contiguous control plots that decreased to non-significance as the distance between plot entries increased. Townley-Smith and Hurd (1973) compared the moving mean method of adjusting plot yields with the percentage of adjacent control plot and the analysis of covariance and concluded that several types of adjustment may be needed to obtain the most reliable results. Baker