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COMPARISON OF ORIGINAL AND IMPROVED MAIZE POPULATIONS THROUGH THE USE OF HYBRIDS DERIVED FROM SETS OF RANDOM LINES

by

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COMPARISON OF ORIGINAL AND IMPROVED MAIZE POPULATIONS THROUGH

THE USE OF HYBRIDS DERIVED FROM SETS OF RANDOM LINES

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INTRODUCTION

The use of inbreeding and hybridization techniques by corn breeders for the development of new and improved corn genotypes is limited by the amount of genetic variation among the lines involved. Greater response from the development of new hybrids will only be achieved through the improvement of base populations from which lines are derived. The recent emphasis on the genetic vulnerability of the corn crop due to its narrow genetic base and on the utilization of new and exotic sources of germplasm has resulted in a return to some degree of population improvement work in both experiment stations and in the hybrid corn industry. Though populations or synthetic varieties will not replace the single, three-way, and double cross hybrids grown in the corn fields of the United States, the corn hybrids of the future will surely be crosses of lines derived from improved populations.

Breeding schemes have been devised which utilize different kinds of the genetic variances which exist in the populations. Prediction of response through the use of recurrent selection programs is possible when estimates of the genetic variances are available. The kind of population improvement scheme likely to be most effective in achieving the desired goals can then be determined. More information is needed, however, on the intermediate and ultimate effects of the various population improvement procedures.

Gardner (1961, 1968, 1969, 1976) has used thermal neutron irradiation and/or mass selection for grain yield to develop two improved populations of corn from the original variety, Hays Golden. Although the irradiated populations, which received two doses of thermal neutron seed treatment in the early cycles of selection, had greater

additive genetic variance than the control, mass selection in both selected populations has resulted in similar increases in yield and in other correlated traits. Information is needed to determine if mass selection has indeed resulted in significant genetic changes in the two improved populations and if the two selected populations differ genetically. The objective of this study was to compare hybrids derived from sets of random inbred lines of the three populations (original, control selected, and irradiated selected) to obtain genetic information about yield and some other quantitative traits in the improved populations in comparison with the original variety, and to use this genetic information to compare methods of predicting three-way and double cross performance.

LITERATURE REVIEW

Mass Selection for Population Improvement

Mass selection is probably the oldest form of artificial selection in existence. It was primarily responsible for the improvement of early open-pollinated corn varieties and the adaptation of these varieties to the varying conditions under which they were grown. Because of its relative ease of operation and apparently successful results, mass selection and a modification, ear-to-row selection suggested by Hopkins (1899), were practiced up to the first quarter of the twentieth century by farmers and corn breeders alike. Smith (1909) was one of the first to report on the effects of mass selection. By breeding the open-pollinated variety Leaming in opposite directions, he was able to produce two strains with a difference in ear height of about three feet, but no difference in yield. In this ear-to-row system, only the highest yielding plot rows were selected from which seed ears were chosen with reference to height.

In Nebraska, Montgomery (1909) reported a yield increase of 9.5 bushels per acre by ear-to-row selection for four years in the variety Hogue's Yellow Dent. However, a later report by Kiesselbach (1922) indicated no improvement in populations of either Hogue's Yellow Dent or Nebraska White Prize due to ear-to-row selection. Kiesselbach's report was published about the time that inbreeding and hybridization results were becoming readily available, and there was a growing belief that mass selection and ear-to-row selection were ineffective in increasing yield. Richey (1922) reviewed the literature on selection work and reported that while mass selection appeared to be effective on quantitative traits like ear and plant height, ears per plant, etc.,

it apparently was not effective on yield. One reason given for this by Richey was that the selection was practiced for attractive ears which would rate highly on a state fair score card but would not necessarily produce high-yielding progenies. Subsequent investigations on this subject led to the conclusion that slight physical differences were of no value in determining the relative productiveness of good seed ears. The evidence favored total production per plant as a basis for selection rather than size or number of ears. Richey concluded that with unknown limits of progress, mass selection on the basis of production and quality was entirely warranted. With ear-to-row selection, however, Richey wrote that there appeared to be little to recommend ear-to-row breeding as a practical method of corn improvement although an entirely unselected or unadapted variety might be improved by a few years of intelligent ear-to-row selection.

Richey (1922) also reported on pure-line breeding which was shown to result in increased as well as decreased yields when compared to the original varieties. With the use of double crosses to eliminate poor seed and poor female parent condition as suggested by Jones (1918), increased yields were obtained. Richey stated, "...the entire evidence from all corn breeding investigations for the present points to pure-line methods as the only sound basis for real improvement of corn." Mass selection programs were then apparently abandoned in favor of the yield advantage and anticipated progress from hybridization.

Considerable genetic variance for yield was believed to exist in the open-pollinated varieties, and Hull (1952) implied that the genetic variance was largely non-additive. Thus mass selection would not be expected to be effective. However, the development and use of mating

design I by Robinson et al. (1949) and mating design III by Gardner et al. (1953) facilitated the estimation of average degree of dominance and of the amounts of additive and nonadditive genetic variances in maize. These reports were based upon hybrid populations derived from single crosses of inbred lines where frequencies of genes at all segregating loci would be expected to be 0.5. They found estimates of additive genetic variance to be greater than nonadditive variance, which indicated that selection of single plants or among progenies should be effective in improving yield, plant and ear height, and ear number in those hybrid populations. Also, estimates of the average degree of dominance suggested that overdominance may exist at some loci affecting yield. Estimates for other traits indicated only partial dominance for genes controlling those traits.

Comstock and Robinson (1952) suggested that the evidence for overdominance could actually have been due to a linkage bias. When linkage is present, predominately in the repulsion phase, the estimates of average degree of dominance are biased upwards. Since quantitative traits such as yield are presumed to be controlled by a large number of genes, it is very likely that linkage exists, especially when the F_2 generation is considered as the base population upon which the estimates are based.

From a design III experiment utilizing the F_2 and F_8 generations of a cross between two homozygous lines, Gardner and Lonnquist (1959) found the degree of dominance and dominance variance to be lower in the F_8 than in the F_2 generation for every quantitative trait studied. Consistently higher additive genetic variance in samples of the F_8 generation than those of the F_2 generation was further evidence for linkages

of genes in the F_2 generation which were broken down through generations of random mating to allow for more recombination to occur in the F_8 than in the F_2 generation.

The above results indicated the need for a genetic evaluation of populations in linkage equalibrium such as open-pollinated corn varieties or advanced generations of a cross between two homozygous lines. Robinson et al. (1955) reported on three southern prolific varieties, Jarvis, Indian Chief, and Weekley. Mating design I was used and additive genetic variance was estimated to be considerably greater than nonadditive genetic variance. For yield in Indian Chief and Weekley the ratio of dominance to additive genetic variance was 0.52 and 0.33, respectively, while the estimate of dominance variance for Jarvis was negative. Thus it must be concluded that over-dominant loci were not the single important source of genetic variability for yield in these open-pollinated varieties even though overdominance could not be proven insignificant.

Robinson et al. (op cit.) advanced two possibilities to reconcile the presence of considerable additive genetic variance with the ineffectiveness of earlier intra-variety selection. One was the negative genetic correlation between grain yield and the components of net reproductive capacity. Genes controlling the remaining variability for the trait undergoing selection may have had a dual purpose: positive for the trait selected and negative for reproduction. This situation probably would not occur until variability was exhausted among genes having only a single effect for the trait being selected. The other possibility was that the gene frequencies at loci providing most of the additive genetic variance were already at equilibrium between the

forces of mutation and selection, thus continued selection effort would operate only to maintain the equilibrium rather than to increase mean yield. Because of the large amounts of additive genetic variance in relation to dominance variance, Robinson et al. suggested that the effectiveness of intra-variety selection should be thoroughly re-examined.

In 1955 Gardner (1961) initiated a mass selection program using the open-pollinated variety, Hays Golden. At the same time he started a recurrent irradiation program in conjunction with the mass selection program. Seeds of the irradiated population were treated with thermal neutrons prior to the first and third cycles of selection. Because of severe radiation damage to the resulting plants, the irradiation treatment was discontinued after the third cycle. Gardner's study involved growing the irradiated and control populations in separate isolations, allowing for random mating within each population. At harvest time, each population was divided into small grids containing 40 plants each. Ears from the top 10% or four plants were selected by weight from each grid, and equal seed samples were taken from each ear to provide seed for the next cycle. Yield was the primary criterion of selection; however operationally, this proved to be selection against lodging and disease. Diseased and/or lodged plants were seldom, if ever, competitive with healthy erect plants. A linear regression coefficient of yield on number of cycles of selection was computed to be 3.93% gain per cycle after four cycles of selection in the control mass selected population. No progress was made in the irradiated population until the irradiation treatment was discontinued.

Lonnquist et al. (1966) reported gains in productivity over the

parent population of 12.7% for the control and 10.9% for the irradiated population after six cycles of selection. No decline in additive genetic variance for yield was observed in the selected populations when compared to the unselected parent population, while there was some indication of an increase in additive genetic variance in the irradiated population. There was also an increase in additive genetic variance for prolificacy in the irradiated population. Ratios of dominance to additive genetic variance were inconsistent for yield for the two years the study was conducted, and many estimates of dominance variance were negative or low relative to their standard errors.

Estimates of variance components from the populations after ten cycles of selection (Gardner, 1969) showed a decrease in additive genetic variance in the control population. The irradiated population had substantially more additive genetic variance than the control and almost as much as the parent variety. For prolificacy, additive genetic variance components followed the same pattern for the various populations as did those components for yield. No difference among populations was noted for additive genetic variance components for days to flower, percent moisture at harvest, or ear height. Although precision on the dominance variance estimates was not great, little differences in magnitude of dominance variance were observed among populations. Significant genotype by environment interactions for the selected populations suggested that perhaps selection had been for genes favorable only in a reasonably good environment and neutral in a less favorable one.

Mean yield comparisons after ten cycles of selection (Gardner, 1968) indicated a gain of 2.72 percent per generation for the control

and 2.53 percent per generation for the irradiated population. However, if calculations were based only on the population after irradiation treatments were discontinued, then a gain of 4.5 percent per generation was observed in the irradiated population. The grain yield in the two selected populations was virtually the same after ten cycles, whereas the irradiated population had a considerably greater number of ears per plant than the control. Prolificacy in both populations was greater than in the unselected parent population. Increased plant and ear height, and later maturity were also observed in the selected populations.

Prediction of continued response from selection after ten cycles (Gardner, 1969) indicated that more progress can be expected from the irradiated population. However, no yield plateau had been reached in either selected population. Compared to mass selection efforts in the first quarter of the century, Gardner's yield improvements were substantial. He attributed this to an abundance of additive genetic variance in the variety Hays Golden and to the use of his refined mass selection technique which minimized environmental effects and increased the probability of selecting the higher yielding genotypes.

Other workers have also realized significant gains through the recent use of mass selection techniques. Johnson (1963) reported a yield gain of 33 percent over the original variety following three cycles of mass selection in a Mexican white dent corn variety. He used a stratified mass selection technique similar to that of Gardner. No differences in lodging or flowering dates were observed in his selected population when compared to the original. Lonnquist (1967) reported yield gains of 6.28 percent per cycle in a population of Hays Golden

selected strictly on the basis of prolificacy for five cycles. His selection intensity was approximately five percent, twice as intense as Gardner's ten percent. The greater precision of measurement and higher heritability for prolificacy than for yield and the high genetic correlation between the two traits enabled the indirect selection to be very effective in increasing yield. Stratified mass selection by Vega and Agudelo (1972) in two South American open-pollinated varieties of maize resulted in significant improvement in one variety and a lack of progress in the other. A yield gain of 17.83 percent after three cycles of selection or 5.87 percent per cycle was observed for the variety "Criollo de falcon." The authors attributed their lack of progess in "Antigua grupo 2" to a lack of sufficient additive genetic variability, fallacies in the selection technique, and insufficient precision to detect small differences.

Arboleda-Rivera and Compton (1974) tested the effects of mass selection for yield and prolificacy for direct and indirect environmental responses in three subpopulations of "Mezcla Varietalas Amarillos." Direct responses of 10.5 and 2.5 percent per cycle were obtained in the rainy and dry seasons, respectively by mass selection for yield. Indirect responses were not as satisfactory. By mass selection for prolificacy, direct responses in number of ears per plant of 8.8 and 4.4 percent per cycle for the wet and dry seasons, respectively were observed. By selecting for prolificacy in the dry season and evaluating in the rainy season, a gain in ears per plant of 11.4 percent per cycle was obtained; but only 1.0 percent gain per cycle was achieved with the opposite mode of selection. Selection for prolificacy is apparently more effective when practiced under weather