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ESTIMATION OF SYNTHETIC VARIETY YIELDS IN PEARL MILLET THROUGH PARENTAL LINE EVALUATION, *per se* AND IN TESTER COMBINATIONS

by

Rowland M. Chirwa

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DISSERTATION TITLE

Estimation of Synthetic Variety Yields in Pearl Millet Through Parental Line Evaluation *Per Se* and in Tester Combinations

BY

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GRADUATE COLLEGE
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ESTIMATION OF SYNTHETIC VARIETY YIELDS
IN PEARL MILLET THROUGH PARENT LINE EVALUATION,
per se AND IN TESTER COMBINATIONS

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Three pearl millet (*Pennisetum glaucum* (L.) R. Br.) synthetic varieties were synthesized each from a different designated set of unrelated parental lines. Each set of parental lines was evaluated for general combining ability in two ways: a) through a sample of paired testcrosses in a central circulant partial diallel; and b) through topcrosses using a common unrelated variety tester. The two methods agree in identifying parental lines with good and poor combining abilities.

Yield for each of all possible single cross hybrids in each set were predicted by summing the actual mean yield of the F_1's and the general combining abilities of the two parents involved in the cross. Predicted mean yields of the F_1's were equal to the actual mean yield of the F_1's. The mean yields of the F_1's and mean *per se* yield of the parental lines were used to predict yields of synthetic varieties. Two formulae: 1) Wright's; and 2) Busbice's were used to predict yields of synthetic varieties.

Predicted yields of the synthetic varieties using

Wright's and Busbice's formulae were similar. Predicted synthetic variety yields using combining abilities derived from topcrosses were 12% higher than predicted yields using testcrosses. Comparison of predicted and actual yield of Syn 3 showed that predictions using testcrosses were similar to the actual yield and those using topcrosses were 17% higher than the actual yield.

Although topcrosses and testcrosses are both useful in selecting parental lines for a synthetic variety, based on general combining ability, the use of heterosis derived from topcross F_1's to predict yield of a synthetic variety, either through Wright's or Busbice's formula is inappropriate. Only testcrosses provide information on average heterosis that is comparable to the expected heterosis in a synthetic variety.

The proportion of selfing in pearl millet populations influences the predictions, estimates at 20% selfing seem to be close to the actual performance. Average synthetic variety yields were 30% over the mean yield of the parental lines, showing a considerable amount of heterosis. The highest yielding synthetic variety was made from a set of parental lines that had a high mean yield and a high mean yield of the F_1's. The parental worth for yield is shown to be positively correlated to that for plant height. Plant height and days to bloom in synthetic varieties can be predicted in the same way yield is predicted.

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INTRODUCTION

Pearl millet, *Pennisetum glaucum* (L.) R. Br. [syn. *Pennisetum americanum* (L.) (Leeke)] is a diploid (2n = 14) and an outcrossing species. It is a staple cereal for millions of people of the less developed countries in the semi-arid tropical and sub-tropical regions of Africa and Asia (Williams and Andrews, 1983 and Andrews et al, 1985) where approximately 15 and 13 million hectares respectively are planted every year (FAO, 1978). Due to its ability to withstand high temperatures and severe moisture deficits, it is better adapted to stresses limiting production in these areas than are other cereals. However, pearl millet rapidly recovers to fully exploit periods of favorable conditions when they occur (Bidinger et al, 1982). Areas where the crop is grown are characterized by high temperatures, low and poorly distributed rainfall, soils of marginal fertility and the presence of diseases and pests. Currently, the infrastructure situation (lack of large cereal markets and commercial grain processing facilities) and the harsh crop growing conditions do not make hybrids feasible as the principle type of cultivar for the small scale, low resource and basically subsistent farmer. Improved varieties therefore become the best current solution to provide such farmers with better genotypes.

The basic advantages of pearl millet varieties are: 1) ease and rapidity of seed multiplication; 2) farmers can retain part of their crop as seed for a generation; and 3) the

varieties provide cultivar types that are in the natural biological state for the species to obtain the best levels of adaptability and stability of performance - characteristics which are extremely important in low resource agriculture. In essence, in a random mating variety each individual plant is genetically unique which leads to less genotype by environment interaction (more stability across environments) for varieties compared to hybrids (Witcombe et al, 1983). Allard and Bradshaw (1964) and Lerner (1954) have used the terms genetic homeostasis and population buffering to describe the stability of a group of plants that exceeds that of its individual members. However, there are instances of certain specific hybrids giving highly stable performance as in corn, but not so far in pearl millet. Most if not all pearl millet single cross grain hybrids to date have collapsed after a few years in commercial use due to breakdown of disease resistance (Andrews et al, 1985), a cause of strong genotype by environment interaction.

Generally breeding programs may take a long time to become productive, and are costly. Making a good variety can be difficult and also takes time. Many varieties have shown great promise in the early generations of breeding only to turn out to be disappointingly mediocre upon final testing in advanced generations (Busbice and Gurgis, 1976).

There are two basic ways in which varieties can be made in pearl millet: 1) as products of a recurrent selection

program on populations, via selecting groups of superior non inbred progeny to make experimental varieties; 2) from products of a pedigree program when a complementary group of parents are chosen from among lines of unrelated parental origins to make a synthetic variety. It is the latter type of variety with which this research deals.

A plant breeder has many challenges. Obviously, in relation to variety production there is need for a tool or a method with which to predict yield of a synthetic variety through the evaluation of contributing parents and thereby increase the probability of making better synthetics. Indeed, the importance of such a tool has long been realized. Busbice and Gurgis (1976) pointed out that one can not breed and test all possible synthetics from a set of potential parents. Rather they suggested that one must be able to predict the yield of such varieties from a knowledge of the genetic potential of the parents and the dynamics of variety synthesis.

This research utilized: 1) material existing in the UNL pearl millet pedigree breeding program; 2) plant breeding theory developed at UNL and elsewhere, mostly on maize and alfalfa; and 3) biometrical genetics expertise to estimate specific and general combining abilities of parental lines that were used to make a synthetic variety.

The objectives are: 1) to identify the type of crosses (testcrosses or topcrosses) which can best predict the

performance of the variety from a set of parental lines; 2) to validate the predictions across environments; 3) to validate predictions using three different varieties; 4) to compare predictions with actual performance of the varieties across environments; and 5) to extend the prediction theory to other traits, plant height and days to bloom.

LITERATURE REVIEW

1.0 Formation of yield in Pearl Millet

When considering yield expression in pearl millet one needs to understand how yield is made up in this crop, both morphologically (yield components) and genetically.

1.1 Yield components

The number of authors who have studied characters associated with grain yield in pearl millet are too many to list, but Rachie and Majmudar (1980) give a good review. Pearl millet, being a highly tillering plant, is capable, depending on conditions of producing more than one head per plant. Total grain yield per plant is a function of number of heads, head size, grain size and number of grains. Total yield per plant is shown to be highly correlated with number of heads, head diameter and length (Bidinger et al., 1971). Tillering like other yield component traits is heritable. Intuitively, (if there was to be only one harvest) a genotype that has more heads per plant would be expected to yield better than one with fewer heads, assuming head size, grain size and number of grains do not decline. Gupta and Singh (1967) concluded that grain yield depends on moderate earliness, tillering, grain size and density (hardness).

Heritabilities of some yield component traits have been reported. Burton (1951), reported some high heritability

values for head length and low values for grain yield, however, Athwal and Gupta (1966) reported very high heritability for grain yield, grain size, heading date, head diameter and head length.

1.2 Nature of gene action for yield components

Gupta and Singh (1970) reported on the nature of gene action covering grain yield and some yield components in pearl millet. They observed that head number, diameter and length show partial to overdominance, indicating that non-additive gene effects are important. However other authors, Jain et al (1961), Gill et al (1968),and Gupta and Nanda (1968) have reported that additive gene effects are important in the inheritance of both head length and diameter. Tillering capacity shows complete negative dominance, low being dominant to heavy tillering. Yield per tiller showed close to full dominance and conspicuous epistatic effects. Grain yield is said to show additive, overdominance and epistatic effects (Gupta and Nanda, 1967, Gupta and Singh, 1970 and Rai et al, 1985). Thus both additive and non-additive genetic effects have to be considered when selecting for grain yield. Supporting the same theory Gupta and Nanda (1967) have also shown that both general combining ability (gca) and specific combining ability (sca) are important when considering grain yield in pearl millet.

In corn (*Zea mays*), a crop that has similar breeding

properties to millet, the type of gene action for yield and other quantitative characters has been the subject of considerable discussion among geneticists for many years. Hallauer and Miranda (1981, 1988), Hallauer (1988) and Hull (1945) have suggested that if heterozygous superiority (over-dominance) is of most importance for yield then selecting for specific combining ability is likely to be the most effective procedure for developing hybrids. But if additive genetic variance is present in significant amounts in corn populations, as suggested by many experiments, then selection for general combining ability may be more effective. Both these theories are as a matter of fact reflected in many corn breeding programs where lines are evaluated for general combining ability first, followed by evaluating the selected lines on their specific combining ability in single cross hybrid combinations (Lonnquist and Rambaugh, 1958). The same authors, Lonnquist and Rambaugh have suggested that if the objective is to produce synthetic varieties, selection based on additive genetic merit (general combining ability) upon which improved yields of synthetics depend, should suffice.

1.3 Inbreeding effects on yield and its components

As a naturally cross pollinated crop, pearl millet suffers from inbreeding depression in the same manner corn does. Burton (1952) reported a substantial reduction in seed

size and number due to selfing. Pokhriyal et al. (1966) showed grain yield depression up to 33% in F_3 generation. Khadr (1978) and Rai et al. (1985) have reported high inbreeding depression, which suggests dominant genetic variation is important in pearl millet. Based on Rai et al.'s (1985) findings Singh et al. (1988) have suggested that pearl millet varieties which are highly heterozygous would be expected to be superior in yield.

1.4 Heterosis for yield

Heterosis for grain yield has been reported in pearl millet by Rachie et al. (1967), where millet hybrids in India have exceeded yields of local improved varieties by an average of 74-197% over a three year period from 1964-67. Lambert, (1984) observed considerable heterosis from pearl millet variety crosses in West Africa. Discussions on heterosis in corn have been covered in detail in Hallauer and Miranda (1981, 1988), which lead to the conclusion that heterosis and its resulting influence on grain yield is primarily due to dominant and partially dominant gene action. This is reflected in the breeding procedures to test new lines for general combining ability first, then for specific combining ability on selected lines (Comstock et al., 1949 and Lonnquist, 1953).

2.0 Breeding pearl millet

Pearl millet, like corn, is a highly cross-pollinated crop, but far more quantitative genetic studies and population improvement procedures have been developed on corn (Hallauer and Miranda, 1981). The information available on corn may be of value to pearl millet breeding programs. The genetic response of these two crops to selection for example is expected to be similar (Rai and Andrews, 1984).

In breeding pearl millet one has a choice of whether to breed varieties or hybrids. The two are not mutually exclusive but differences do exist in parental choice and in evaluation tests.

a) Hybrids

Hybrids are easier to breed and make in corn than in pearl millet. In order to make a hybrid in pearl millet, a seed parent carrying cytoplasmic/genetic male sterility must be first produced, and the male (pollen) parent found which restores male fertility. An alternative method of making hybrids through the use of natural protogyny in pearl millet is currently under investigation. If successful, this may offer flexibility of parental choice, as in corn. Thus, in most pearl millet breeding programs, apart from varieties, considerable effort is being devoted to hybrids.

b) Varieties

Varieties in pearl millet are in effect superior

heterogeneous populations containing a controlled range of genetic variability. This confers a type of stability not available to hybrids and varieties in self pollinated crops. There are variations of two basic procedures by which varieties are developed in pearl millet: 1) through various methods of recurrent selection in inter- or intra-population improvement programs (experimental varieties); 2) through utilization of products of a pedigree breeding program (synthetic varieties). The essential difference between these two methods is that the former: i) has a genetic base derived from the parental population; and ii) is made up of related parents but not inbred progenies which permits resultant varieties to contain a wider gene and allelic base for polygenically controlled traits. Conversely, the latter method, where the parents are homozygous, but unrelated, produces varieties where the nature of variability is different, caused by the prior inbreeding of the contributing parental lines.

2.1 Selection of parents

When making varieties or experimental varieties from a recurrent selection breeding program, the performance of progenies *per se*, has been the major criterion for selection as parents. Singh et al. (1988) have suggested that varieties formed by exerting high selection differential on the parents

may not necessarily be the highest yielding. They have attributed such a weak correlation between selection differential and variety performance to: 1) performance *per se* may not be a good estimator of combining ability; or 2) yields are estimated with high experimental errors; or 3) different numbers of parents give different amounts of inbreeding depression. Considering the foregoing problems, Singh et al. (1988) have suggested to evaluate progenies for recurrent selection or for identifying parental lines (for experimental varieties) by estimating their general combining abilities using a topcross method - an approach also recommended by Lonnquist (1968).

In synthetic varieties, the parents may be evaluated for general combining ability prior to variety formation. Only lines with good combining ability are intermated to make a synthetic variety (Lonnquist, 1949). Considering the number of lines that a breeder works with, a question arises as to the number of synthetic varieties that a breeder can make from all possible potential parents. Busbice and Gurgis (1976) pointed out that one can not breed and test all possible synthetics from a set of potential parents. Rather they suggested that one must be able to predict the yield of such varieties from a knowledge of the genetic potential (breeding value) of the parents through their cross-performance and the dynamics of variety synthesis.

2.2 Inbreeding effects in synthetic varieties

Wright (1922) observed that the primary effect of inbreeding (mating between relatives) is the reduction in heterozygosis leading to loss in yield. Such loss in heterozygosis has been expressed by the coefficient of inbreeding, F (Wright, 1921 and Kempthorne, 1957). Various authors have discussed the concept of inbreeding in synthetic varieties (Wright 1922, 1938; Busbice 1969, 1970 and Kinman and Sprague, 1945). Parents are considered as generation Syn 0, and the bulk offspring generated by cycles of random mating as Syn 1, Syn 2 ...Syn t. Because the number of parents is small and the parents are homozygous, relatives carrying genes of the same origin will mate more frequently in the process of random mating, until an equilibrium is reached, resulting in reduced level of heterosis caused by partial inbreeding depression.

Busbice (1969) demonstrated the computation of inbreeding in any generation of a synthetic variety. His computations give an insight regarding: a) the number of parents that should be included in Syn 0 of a synthetic variety; b) the effect that the level of homozygosity of the parents and the relationship among them (coefficient of ancestry) will have on advanced generations; and c) the consequent change in vigor that may occur in successive generations of random mating.

A solution to the problem of computing inbreeding in