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COMBINING ABILITY FOR AGRONOMIC TRAITS IN F1  
GRAIN SORGHUM HYBRIDS.

THE UNIVERSITY OF NEBRASKA - LINCOLN, PH.D.,  
1978

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PREVIEW

COMBINING ABILITY FOR AGRONOMIC TRAITS IN  
F<sub>1</sub> GRAIN SORGHUM HYBRIDS

by

Roberto Ritter

A DISSERTATION

Presented to the Faculty of  
The Graduate College in the University of Nebraska  
In Partial Fulfillment of Requirements  
For the Degree of Doctor of Philosophy  
Department of Agronomy

Under the Supervision of Professors

W. M. Ross and C. Y. Sullivan

Lincoln, Nebraska

September, 1978

TITLE

COMBINING ABILITY FOR AGRONOMIC TRAITS IN

F<sub>1</sub> GRAIN SORGHUM HYBRIDS.

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## ACKNOWLEDGEMENTS

The author wishes to express his deepest gratitude to Dr. W. M. Ross for his continued assistance during the course of this study and during the preparation of this manuscript and to Dr. Rosalind Morris for her assistance in the preparation of this manuscript. The gratitude of the author is extended to Dr. C. O. Gardner for his critical reading of this manuscript and to Drs. C. Y. Sullivan, M. D. Clegg and R. B. Clark for also serving on the supervisory committee. Appreciation is extended to Dr. J. W. Maranville and to the crews of the Sorghum Breeding and Physiology Projects who helped in the gathering and analysis of the data used.

The writer wants to thank the Food and Agricultural Organization of the United Nations for the economic support and the Universidade Federal de Santa Maria, Brazil, for granting leave to accomplish this graduate work.

The author is indebted to Dr. W. M. Ross and his wife, Joyce, for the attention given to him and his family during their stay in the United States.

Para

Ione, Paula & Patricia

PREVIEW

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## INTRODUCTION

Grain sorghum (Sorghum bicolor (L.) Moench) is the world's fourth most important cereal and is grown on all inhabited continents. Most of the sorghum produced in the world is used for food. Because of this, it is important to consider quality components, such as protein content and quality and oil content, besides grain yield in breeding programs. Emphasis also should be given to the development of varieties able to produce the maximum yields allowed by the environment where they are grown. Where sorghum is grown mainly for feed, the same attributes and goals should be considered.

Sorghum traditionally has been cultivated in marginal areas having environmental stresses, such as excessive heat or low moisture availability, where corn production is hazardous or uneconomical. The ability of sorghum to stand heat and drought stresses makes it appropriate for regions where high temperatures and lower moisture situations are probable.

If a breeding program is to be successful, it is necessary to fully exploit the great variability that exists within the genus Sorghum, and to test the largest possible number of genotypes to identify strains adapted to these



environments. When hybrid varieties were introduced in the 1950's, it became clear that higher-yielding  $F_1$  combinations could only be secured by the use of improved parental lines. Subsequent breeding for parents with better quality and higher yields became part of the breeding philosophy. The diversification of male-sterile (A) and fertility restorer (R) lines used to make hybrids and the search for parental genotypes with maximum yielding ability were demanded by both the need for maximum returns for the inputs used and by the need to reduce the genetic vulnerability in the crop.

The development of A and R lines of sorghum and their evaluation follow patterns characteristic for species where utilization of hybrid vigor is economical. Comparing recently developed lines together with established ones in all possible hybrid combinations are important steps in a breeding program where utilization of hybrids is considered. As  $F_1$  hybrid performance is dependent upon the genetic make-up of the parental lines, the evaluation of these lines has to consider both their agronomic performance and their ability to produce higher yields when in a particular combination or in a set of crosses.

The average performance of an inbred line in a set of crosses is its general combining ability (GCA) according to Sprague and Tatum (1942). To "distinguish those cases in

which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved", they created the concept of specific combining ability (SCA) which applies to situations where a particular parental combination greatly deviates from the average performance of the parents.

The use of genetic male sterility in sorghum gave the breeders a new tool and permitted breeding methods previously available only to cross-pollinated crops. The isolation of potentially useful parental lines was now possible from improved populations obtained using these methods. Final evaluation of the lines has to be done, however, by crossing in all possible combinations the genotypes considered potentially useful.

The success of any breeding approach in identifying better parents and hybrids is determined by the type of gene action influencing a given trait. The determination of the kinds of variances involved in the manifestation of a characteristic, and their relative importance compared to each other, are important for the decisions a breeder has to make regarding the handling of his material and selecting the most efficient breeding schemes.

Variation in a group of genotypes can be caused by additive, dominant, and epistatic genetic effects. The first

is important in the expression of the GCA; the other two determine SCA and heterosis of a trait. The determination of their relative importance is essential regarding plant breeding decisions.

The purposes of this study were as follows:

1. To study a set of  $F_1$  hybrids obtained from crosses involving parental lines developed by the Nebraska and other Experiment Stations.
2. To evaluate their combining ability and estimate the relative importance of GCA and SCA in determining agronomic and physiologic traits.
3. To determine the kind of association (correlations) existing among the several traits studied both in the parental lines and in the  $F_1$  hybrids obtained by intercrossing them, and
4. To calculate the ratio of genetic and phenotypic variances for the traits studied.

## LITERATURE REVIEW

### Biometrical Approaches

Information on the relative importance of GCA and SCA is needed in conducting efficient plant breeding programs, especially for those crops where the use of heterosis and production of  $F_1$  hybrid seed is economically feasible. The value of an inbred line is determined by characteristics of the line alone and in combination with others or, in other words, through the estimation of its general and specific combining ability.

Fisher (1918) partitioned the variance of a population into three components: an additive variance due to the average effect of genes, a dominance variance due to allelic interactions, and a variance of epistatic effects due to interactions of non-allelic genes.

Sprague and Tatum (1942) formalized the concept of general and specific combining ability. They defined GCA as the "average performance of a line in hybrid combinations", and SCA referred to situations when "certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved". Methods for estimation of both GCA and SCA variances were presented. Low SCA variances indicated that parental lines

involved in a hybrid combination performed as expected based on their GCA. High SCA variances, however, indicated that some combinations did relatively better or worse than expected. SCA was largely dependent on genes with dominance and/or epistatic effects. They found that in previously unselected material, GCA was three times as large as SCA; when material already selected was considered, variances for SCA were 10% larger than those for GCA. Apparently in the first situation, genes with additive effects were either more common or produced greater effects than genes with dominance or epistatic effects. In the second situation, genes for differences in GCA had been eliminated, and those for SCA became important.

Rojas and Sprague (1952) studied the interaction of GCA and SCA with locations and years. The SCA x year and SCA x location interaction variances were consistently larger than the corresponding estimates involving GCA. The authors suggested that SCA variances included a considerable part of the genotype x environment interaction besides nonadditive deviations due to dominance and epistasis.

Falconer (1960) referred to both GCA and SCA as mean values of the  $F_1$ 's of a line crossed to others and as deviations of a cross from the average GCA of the lines, respectively. When lines X and Y are crossed, their mean value

can be expressed as  $MEAN(XY) = GCA(X) + GCA(Y) + SCA(XY)$ . The last term is the interaction component, and differences in GCA and SCA are due to additive and additive x additive variances for GCA and dominance and epistatic variances for SCA.

Comstock and Robinson (1948, 1952) presented the mathematical basis for estimation of additive and dominant gene effects on populations of biparental progenies. Additive and dominant portions of variance of genetic effects were explained by regression of the number of positive genes on the genotype and variance of deviations of the genetic effects from that regression, respectively. Analysis of variance procedures to estimate additive and dominance variances and their genetic interpretations were given with no linkage and no epistasis assumed. If the assumptions do not hold true, variances will be biased upward, especially the variance due to dominant gene effects. In these procedures, each male is mated to a series of females (nested design), or each female parent is mated with each male individually (design II).

Cockerham (1954, 1956) presented an extension of the concept of partitioning hereditary variance for analysis of covariances among relatives when epistasis is present. The subdivision of the epistatic variance and the distribution

of these components in the covariances among relatives were presented. Analysis of variance with expectations of mean squares in terms of covariances between relatives, as well as genetic interpretation when inbreeding occurs, were presented. Kempthorne (1957) also presented the format of analysis of variance, mean squares expectations in terms of covariances, and genetic interpretations. Gardner (1963) summarized some of the estimates of genetic parameters obtained for quantitative traits in cross-fertilized crops and discussed several designs associated with them.

Diallel crossing systems, in which a set of  $p$  inbred lines is chosen and crossed among themselves yielding a maximum of  $p^2$  combinations, have been intensively used in genetic research. Yates (1947) first proposed the diallel mating design. He assumed that effects of parents are additive, and any departures from additivity are random and independent. Jinks and Hayman (1953) presented a particular method for analysis of a diallel table, and Jinks (1956) extended the theory of the diallel analysis of parental and  $F_1$  lines to include  $F_2$  and backcross generations. Genetic effects, including the partitioning of epistasis, were obtained.

Griffing (1956a) presented an evaluation of the use of diallels in quantitative studies. Additive and nonadditive components of parental genotypic variance could be estimated

using GCA and SCA effects. A detailed study (Griffing, 1956b) of procedures, restrictions and assumptions underlying diallel analysis, was presented. The exact genetic interpretation can be obtained only when a random set of genotypes is used. Four experimental methods and two sampling situations were discussed.

More recently Gardner and Eberhart (1966) presented a model for estimation of genetic effects from diallel crosses and related populations of a fixed set of random mating varieties. The model is also appropriate for inbred lines, and deviations from it can be used to test epistasis and linkage.

Eberhart et al. (1967) proposed a comprehensive breeding system for cross-pollinated crops which extends to crops where random mating can be induced by genetic male sterility, as in sorghum. Webster (1965) was the first to use genetic male sterility to form a random-mating population in sorghum. Doggett (1968, 1972), and Doggett and Eberhart (1968) described mass selection and recurrent selection systems for sorghum. Ross (1973) and Ross et al. (1971) discussed potentials, problems, and accomplishments in sorghum population breeding. Recently, Ross et al. (1976a) determined the range and extent of variability of yield and other agronomic traits in five sorghum random-mating populations. Jan-orn