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ESTIMATES OF GENETIC AND ENVIRONMENTAL COMPONENTS  
OF VARIANCE IN SOME QUANTITATIVE GENETIC TRAITS  
FROM FAMILIES DERIVED FROM THE NP3R RANDOM-MATING  
SORGHUM POPULATION AND THEIR APPLICATION IN  
BREEDING SYSTEMS.

The University of Nebraska - Lincoln, Ph.D., 1973  
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by

Jinda Jan-orn

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Under the Supervision of Dr. Charles O. Gardner and

Dr. William M. Ross

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**TITLE**

Estimates of Genetic and Environmental Components of Variance in Some Quantitative Genetic Traits from Families Derived from the NP3R Random-Mating Sorghum Population and Their Application in Breeding Systems.

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To those who have taught me  
and  
To those involved in my education

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PREVIEW



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## INTRODUCTION

Knowledge about plant character inheritance is very useful to a breeder. In most cases, effective selection can be made, but the success of discriminating genetically among individuals or families is dependent upon knowledge of the nature of the genetic (especially additive) variability expressed from generation to generation. Unlike qualitative characters which can be recognized and classified easily, like black and white, the measurement of quantitative characters is in continuous units. Many genes are generally involved, both directly and indirectly, in governing a quantitative character, and character expression is very sensitive and greatly influenced by environment. Therefore, to get information about a quantitative character, one has to deal with statistics estimated from replicated experiments over various environments. Then information can be obtained in the form of first order statistics (means) and second order statistics (variances). These can be used further for estimating genetic variances and the degree of repeatability accounted for by genetic make-up and for predicting possible future performance under different breeding systems.

Many plant breeders consider quantitative genetic experiments to be tedious work which requires highly specialized training and consumes too much labor; therefore, they do not make use of second order statistics. However, with structured mating designs, practical breeding and genetic studies can be conducted simultaneously in the same experiment. From a planned experiment, genetic variances can be estimated

and used by the plant breeder to help him select the most efficient breeding procedure. There are variations caused by additive genetic effects, which can be transmitted from generation to generation, dominance genetic effects which are often found to be important in hybrids, and sometimes epistatic (non-allelic interaction) genetic effects. Potentially useful materials can be selected from the materials tested in well planned and well designed experiments for use in producing agronomically desirable populations, lines or hybrids.

Sorghum is similar to other self-pollinated crops, where most of the quantitative inheritance studies have been conducted using populations derived from crossing two lines or varieties, which results in a rather narrow germ-plasm base (Liang *et al.*, 1972). Recently, planned random-mating sorghum populations have been developed by combining many lines or varieties into a single germ-plasm pool using genetic male-sterility to facilitate random mating among plants (Ross, Gardner and Nordquist, 1971; Gardner and Nordquist, 1970; Doggett, 1972). Such populations allow the plant breeder to use recurrent selection schemes for improving the genetic potential of sorghum similar to those practiced in cross-pollinated corn. Success from using recurrent selection procedures in sorghum random-mating populations has been reported, and the results of various recurrent selection schemes reported are encouraging (Doggett, 1972).

The objectives of this study were (1) to obtain measurement data on quantitative inherited traits in half-sib, full-sib and  $S_1$  families derived from the sorghum random-mating population NP3R, (2) to estimate genetic and environmental components of variance using analysis of

variance techniques, (3) to predict responses expected under different recurrent selection schemes, and (4) to determine the most effective breeding method for sorghum improvement. The ultimate long-range objective is to select potentially good materials and recombine them on a cyclic basis so that superior genotypes (ultimately lines and hybrids) will be developed for commercial use. Introducing the male sterile gene into the NP3R population has made it possible to impose new breeding systems on this normally self-fertilizing crop (Gardner and Nordquist, 1970).

PREVIEW

## REVIEW OF LITERATURE

### Gene Effects and Relationships Among Traits

As in many other crops, grain yield is the main characteristic to be considered in selection or breeding of grain sorghum; however, it has a relatively low heritability compared to some other characteristics (Liang et al., 1972). Also, it is difficult to evaluate the significance of genetic variance components estimated for grain yield, since they have been reported in various ways depending upon the materials and possibly the methods used.

Generally, and especially in hybrids, both additive and dominant genetic effects are involved in grain yield (Kambal, 1962; Walsh, 1971; Pathanothai, 1972). However, Kambal (1962) and Kambal and Webster (1965) considered additive gene effects to be more important in that they have the advantage of being more stable over different environments. This was confirmed by Pathanothai (1972). In crosses of diverse germ plasm, a much higher degree of general combining ability, which is related to additive gene effects, is usually reported (Kambal, 1962; Beil and Atkins, 1967; Abifarin, 1969). Liang and Walter (1968), Liang (1971), and other authors (Beil and Atkins, 1965; Nagur and Murthy, 1970) imply the existence of epistasis in grain sorghum yield from experiments involving sorghum crosses.

If we ignore number of heads per plant, then the number of seeds per plant and weight per seed are considered to be the most important

yield components. It is difficult to determine which is the more important, as they are confounded with each other in grain yield (Martin, 1928; Anderson, 1958; Brauns, 1961; Kambal, 1962; Wing, 1962; Quinby, 1963; Niehaus and Pickett, 1966; Beil and Atkins, 1967; Doggett, 1969). When data are collected, plant grain yield and weight per 1000 kernels are measured first. Then the number of kernels is estimated by dividing total weight of grain (yield) by weight per kernel. When both number of kernels and weight per kernel are used to determine the contribution to grain yield, a greater contribution has been shown to come from number of kernels which is highly correlated with grain yield (Anderson, 1958; Kambal, 1962; Wing, 1962; Chung, 1970; Atkins and Martinez, 1971).

Although the authors cited in the previous paragraph have probably reached the correct conclusion regarding the relative contribution of number of kernels and weight per kernel to total yield, none of them have evaluated the relationship in the proper manner. Since total yield is the product of number of kernels and weight per kernel, the relative contribution of the yield components to total yield cannot be suitably evaluated by simple linear correlations. One valid procedure may be the comparison of the relative magnitude of the standard partial regression coefficients ( $b_1$  and  $b_2$ ) obtained from fitting the equation:

$$\begin{aligned} \log \text{ total plant yield} &= b_1 (\log \text{ number of kernels}) \\ &+ b_2 (\log \text{ kernel weight}) \end{aligned}$$

where the three variables (log total plant yield, log number of kernels and log kernel weight) are expressed in standard measure (mean = 0, variance = 1).

This procedure may allow one to simultaneously consider the contributions of the yield components to total plant yield. Transforming the original data (total plant yield, number of kernels and kernel weight) to logarithms linearizes the yield function which then permits the use of multiple linear regression techniques (R. F. Mumm, 1973, personal communication). Unfortunately an evaluation of this relationship between yield and yield components in grain sorghum has not been published.

However, as a complex characteristic, grain yield is also related to or influenced by many characteristics directly and indirectly. Doggett (1969), as well as Wing (1962) and Anderson (1958), indicated from experiments involving hybrids that high grain yield in hybrids was caused by a greater number of kernels. Greater number of kernels or florets per plant was claimed to be caused by greater photosynthetic area and efficiency of the plant in addition to greater physiological activity of the root system (Doggett, 1969).

Height is related to grain yield as an indirect effect via growth. Taller plants generally have a larger photosynthetic area and may stay in a longer period of plant and grain development. A positive relation between plant height and grain yield has been indicated by many authors (Martin, 1928; Casady, 1965, 1967; Hadley et al., 1965; Campbell and Casady, 1969; Graham and Lessman, 1966; Graham, 1967; Sandlin, 1970; Schertz, 1970; Windscheffel et al., 1973).

Nordquist (1971) indicated that in the population which he studied, improvement for all traits studied should be possible because of the prominent existence of additive genetic variances. However, all traits will not respond in the same favorable direction. Gain in one might

take place at the expense of another (Benjasil, 1967; Sandlin, 1970; Nordquist, 1971; Doggett, 1972). Height is highly heritable (Quinby and Karper, 1954; Chiang and Smith, 1967; Ciobanu, 1968; Chung, 1970; Sandlin, 1970; Liang *et al.*, 1972); therefore, there should be no difficulty in selecting in either a negative or positive direction. If hand harvesting is practiced, as is done in some parts of the world, height will not cause any problem except for lodging in severe cases of wind damage. However, for machine harvesting in highly developed agriculture, a tall variety is quite undesirable. Even though tall plants are not preferable, they are usually chosen when one is selecting for high grain yield (Rosenow, 1970; Doggett, 1972). In most reported studies, height is included for the purpose of determining an optimum selection procedure or for supplying the necessary information concerning a relationship with grain yield. The information is then used in developing a selection index to increase yield while retaining an acceptable height (Sandlin, 1970).

At least four loci are involved in controlling the time from planting to flowering (Quinby, 1967). Gene effects and their role for maturity in contributing to grain yield are similar to those for height, especially under short daylight conditions. In experiments involving some exotic x Indian sorghum crosses, Rao (1970) indicated that gene effects for maturity as well as for height were essentially additive. A similar result was reported by Chiang and Smith (1967) who studied a 7 x 7 diallel of American sorghum crosses. They also indicated over-dominant gene effects (confounded with non-allelic gene interactions) for maturity as have been reported by Quinby (1967). Like genes controlling other quantitative characteristics, those

controlling maturity are highly interactive with the environment, especially with length of day as reported by Caddel and Weibel (1971) and Quinby (1972). The maturity genes indirectly and directly influenced grain yield via growth including the period of panicle development, leaf number, and leaf area (Quinby, 1972). Like height, maturity was highly heritable and was correlated with grain yield (Liang et al., 1969; Chung, 1970; Gelaw, 1971).

In many publications, the trait heads or tillers per plant is included as one of the components of yield (Martin, 1928; Quinby, 1963; Kirby and Atkins, 1968; Chung, 1970; Anderson, 1958). From a 7 x 7 sorghum diallel cross study, Chiang and Smith (1967) reported a relatively high heritability of 43.2% for number of tillers. A similar result was reported by Chavda and Drolsom (1970) in sudangrass type sorghums. Within materials of narrow genetic background, Liang et al. (1969) and Chung (1970) indicated low heritability estimates for number of heads. In a mutant type sorghum produced by irradiation treatment, Webster (1965) reported that tillering was controlled by a recessive gene tl. Ayyangar (1942) indicated a recessive gene tu controlling uniform tillering which was recessive to Tu controlling delayed tillering in sudangrass. He also indicated a dominant gene Tx which controlled tillering, Tx was dominant to tx controlling single stalk.

The correlations between grain yield per plant and heads (or tillers) per plant are conflicting from one report to another. Graham (1967) and Gelaw (1971) reported significant correlations, but they were different in sign in the two different materials. Liang et al. (1969) and Chung (1970) reported non-significant correlations between number of tillers and yield. The reported relationship between number