REPLICATED field experiments are an integral part of all crop breeding programs. They serve in establishing variety and strain differences for yield and other agronomic traits. Results from these experiments generally are the major criteria upon which the retention or rejection of strains is based. As a result, crop breeders have refined planting and harvesting techniques to minimize the experimental error associated with these tests and have used statistical procedures extensively to analyze variability observed in populations being evaluated. The incorporation of statistical procedures into crop breeding schemes has served to emphasize the importance of determining the optimum size and shape of plots for use in field experiments because the individual plot is the basic unit for most statistical analyses. Furthermore, the fact that crop species usually differ in their responses to environmental components, such as the availability of light, moisture, and nutrients when grown in different planting arrangements, suggests that a plot size and shape satisfactory for experiments with one species may or may not be suitable for experiments with another. Since investigations of this nature with sorghum are limited, the prime objective of the study herein reported was to estimate the optimum size and shape of drilled plots for use in grain sorghum yield trials. A second objective was to compare the relative efficiency of various incomplete block designs in relation to randomized block designs for conducting yield tests.

REVIEW OF LITERATURE

Numerous studies have been conducted since the turn of the century relative to size and shape of plots for field crop experiments. Bibliographies prepared by the American Society of Agronomy Committee on Standardization of Field Experiments (1, 2, 3, 4, 5) and the catalogue of uniformity trials compiled by Cochran (6) are evidence of this. These publications deal with investigations carried out before 1940 and are valuable references to uniformity trials up to that time. Additional studies of this type have been conducted with many crops since then, but few have been reported for sorghum.

The first investigation of plot size and shape in sorghum was reported by Stephens and Vinail (15). They subdivided a field of Feterita variety, planted in 40-inch spaced rows, into 2,000 rod-row units. After studying the reduction in probable error associated with increasing plot size, they concluded that plots 2 rods by 10 rows or 2 rods by 5 rows would be sufficiently reliable for determinations of forage yield.

Results of plot size studies with grain sorghum were first reported by Swanson (17). He harvested 400 single-row plots 2 rods long and spaced 40 inches apart from a field of Dawn kafir. Increasing the plot size from 1/400 to 1/25 of an acre reduced the probable error for grain yield determinations by 54.8%. Additional increases in plot size did not give appreciable reductions in probable error.

More recently, Stickler (16) published the results of two uniformity trials with Plainsman sorghum. In 1 test rows were spaced 14 inches apart while 40-inch row spacings were used in the other experiment. He also reported on 2 additional tests with 40-inch row spacings, using the hybrids RS 610 in 1 test and KS 605 in the other. Estimates of optimum plot size for single row plots spaced 40 inches apart ranged from 70.3 to 90.5 feet in length and were considered unrealistic. Estimates of optimum plot size made from the experiment with 14-inch row spacings ranged from a single row 23 feet long to 1 row 58 feet in length.

Using uniformity trial data from 40-inch row spacings, Webster found that single row plots 10 feet in length had as low a coefficient of variability as plots 4 rows by 25 feet. He estimated the optimum plot size to be from 10 to 20 feet for this type of drilled-row seeding. Through comparisons of coefficients of variability Brown estimated that the optimum plot size for grain sorghum yield tests in 40-inch spaced rows was either 4 rows 5 feet long or 2 rows 15 feet long.

Incomplete block designs were introduced by Yates (18) and have been used extensively in conducting yield trials of crop varieties. However, their relative merit for testing grain sorghum strains has received only limited attention. According to Kramer and King sorghum tests in Texas have been arranged in lattice designs for several years. Analyses of the yield data from 39 triple rectangular lattice designs of 3 replicates each showed an average gain in efficiency for the lattice designs relative to a randomized block design of 34.4%. Gains in efficiency for the lattice arrangements ranged from nothing to 197% for this group of experiments. They concluded, "For ordinary variety testing nothing can be lost from the use of lattices, but much can be gained in the way of efficiencies at some locations".

MATERIALS AND METHODS

Data used in this study were obtained from a field planted to DelKal C44A hybrid grain sorghum in rows spaced 40 inches apart at the Agriculture Farm, Ames, Iowa, in 1959. All rows were hand thinned to a uniform stand of three inches between plants. The field was divided into 2,880 single-row plots each 5 feet in length, and each "basic-unit" was harvested by hand, threshed, and weighed individually. Before weighing, the threshed material was dried to 8 to 10% moisture content. The grain weight for each basic-unit was recorded in ounces on a "master sheet" to permit retention of the field arrangement of plot units.

Different combinations of basic-unit yields were added together and recorded on additional sheets to facilitate the analysis for plots of different sizes and shapes. The plot sizes and shapes analyzed were limited to combinations up to and including 4 rows by 50 feet in length, using data from the entire planting wherever possible. Yields from the terminal 5 feet at each end of a row and the 2 outer rows on each side of the field were omitted from the analyses. Among plot variances, V<sub>xy</sub>, for all plot sizes and shapes were then computed.

The equation x = bKx/(1-0.6Kx), as presented by Smith (14), in which x equals the number of basic units, b is a measure of correlation among adjacent plot yields, and Kx and K<sub>y</sub> are estimated cost factors associated with variations in number and size of plots, was used to estimate optimum plot size. Smith derived this equation after demonstrating that an empirical relationship exists between plot size and plot variance which is expressed by the equation: V<sub>x</sub> = V<sub>y</sub>/x<sup>b</sup>, where V<sub>x</sub> represents the variance on a per-unit basis of plots containing x basic units and V<sub>y</sub> is the variance for plots of one basic unit. When expressed in logarithms the relationship becomes log V<sub>x</sub> = log V<sub>y</sub> - b log x, and from this, b is estimated as a linear regression coefficient.

In this study, b was calculated from the equation:

\[ b = \frac{\sum W_1 \log X_1 \log X_2 - (\sum W_1 \log V_{xy}) (\sum W_1 \log X_2)}{\sum W_1 (\log X_2)^2 - (\sum W_1 \log X_2)^2/\sum W_1} \]

proposed by Federer (8), in which b is weighted according to the degrees of freedom associated with the variance for a given


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