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VARIABILITY OF GRAIN SORGHUM YIELDS AS INFLUENCED BY SIZE, SHAPE, AND NUMBER OF PLATS[1]

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Many experiments have been conducted with field and orchard crops to determine the most suitable size, shape, and number of plats necessary to obtain reliable comparisons of yield. Such experiments on sorghums seem to be limited to those reported by Stephens and Vinall (3).[3] They sub-divided a field of feterita at Chillicothe, Texas, into 2,000 rod-row units. The rows were 40 inches apart and the rod-row units were equivalent to an area of approximately 1/800 acre. The total green weight of the forage in ounces from each unit was used as the basis for computation. From various combinations of the ultimate units into larger plats they concluded that three or four plats, 1/40 to 1/80 acre in size, gave results sufficiently reliable for determination of forage yields of sorghums.

This paper presents data on the influence of size and shape of plats and the number of replications on the variability in the yields of sorghum grain. The data were obtained at the Fort Hays Branch Experiment Station, Hays, Kansas, during the fall of 1923.

PLAT AND NURSERY METHODS IN USE

A questionnaire was sent recently to investigators located at agricultural experiment stations in the sorghum belt to ascertain the size, shape, and number of plats used in varietal tests. Twenty-three replies were received.

Four investigators favored plats less than 1/25 acre in area; 9 used 1/25 acre plats; 6 used 1/10 acre plats; and 6 used no definite size in their experiments. Two investigators favored plats with 2 rows; 6 used plats of 2, 3, or 5 rows; 12 used 4-row plats; and 3 used plats of 8 to 10 rows. As to length, 4 investigators used plats less than 100 feet long; 12 used plats 132 feet long; and 6 used plats of various lengths. The most popular widths between rows were 40, 42, and 44 inches.

The number of replications used varied widely. Five investigators planted single plats on one date, while 9 planted single plats on from two to four dates. Four investigators planted 2 plats of each variety on a single date, 2 used 2 plats for each variety on two different dates,

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[3]Reference by number is to "Literature Cited," p. 838.

and another made two plantings of each variety on three different dates. One investigator planted each variety three times on four different dates and another planted each variety four times on one date.

From the above it appears that the common practice is to plant single 4-row plats 132 feet long and approximately 1/25 acre in size on more than one date. Planting a variety in single plats on two to four dates technically is not replication. This practice is useful, however, in bringing to light many interesting facts regarding the response of sorghums to environmental conditions.

The length of nursery row used by the different investigators ranged from 2 to 10 or more rods. Four rods is a convenient length for a sorghum nursery row. A well-developed sorghum head will furnish sufficient seed for planting two 4-rod rows and leave enough reserve seed to repeat the planting in case a stand is not obtained. A row 4 rods long will produce 75 to 90 plants, a sufficient number for a fair expression of the characteristics of a strain, although not necessarily giving a reliable index of yielding ability.

EXPERIMENTAL METHODS

A pure line selection of Dawn kafir, a variety widely grown in the sorghum belt, was planted in rows 40 inches apart with a surface planter on a well-prepared field at Hays, Kansas, in 1923. This field had been uniformly cropped to wheat the previous year and had been fall plowed. The plants were thinned to a uniform stand 7 inches apart in the row, but there were occasional spaces in the rows having no plants. The largest vacant space in any row was 8 feet in length. In general, the stand was excellent for a field of grain sorghum.

At harvest time a block 50 rows wide and 16 rods long was laid out in the center of the field. The grain was harvested in single-row units 2 rods long, equivalent to an area of approximately 1/400 acre. The yields of each ultimate row were recorded in bushels per acre. Four hundred units were harvested. Since the entire block was in the center of the sorghum field, there was no border effect on any unit.

Ultimate plats varied in yield from 7.1 bushels to 62.5 bushels, but the means of the yields of the various combinations of plats, from 10 up, fluctuated only slightly from the average yield of 31.9 bushels.

Throughout this paper the term "replication" indicates the actual number of plats used and not the number plus one. The formula $0.6745\sqrt{\frac{\Sigma d^2}{n}}$ was used to determine the probable error of the yield of a single plat in all calculations presented here.

REDUCTION OF PROBABLE ERROR BY INCREASING SIZE OF PLATS

The reduction of the probable error due to increasing the size of plat by grouping adjacent plats is shown in Table 1. Whenever possible in a series of increasing size, either the length or the width of the plats was kept constant and the area enlarged by additions in the other dimension. As noted in Table 1, the decrease in probable error is not great after the plat has been increased in size to 1/25 of an acre or more. Increasing the plat from 1/400 of an acre to 1/25 of an acre (8 rods by 13 1/3 feet, a size frequently used) reduced the probable error 54.8%. Increasing the size to 1/10 of an acre reduced the probable error 60.9%. This slight reduction is not sufficient to justify the use of plats as large as 1/10 acre in variety tests of sorghums.

The probable errors shown in Table 1 for the larger plats, i.e., 1/8, 1/6, and ¼ of an acre, are based on a small number of plats and, since no additional land was added to the experiment, less reliability can be placed on the results.

TABLE 1.—*Reduction of probable error by increasing the size of plat of Dawn kafir.*

Approximate size of plat (acre)	Dimensions of plat: Length in rods	No. of rows	Width in feet	Probable error of yields of single plats (bushels per acre)
1/400	2	1	3 1/3	7.57
1/200	2	2	6 2/3	6.87
1/100	2	4	13 1/3	5.82
1/66	2	6	20	5.57
1/50	2	8	26 2/3	5.46
1/40	2	10	33	5.42
1/200	4	1	3 1/3	6.59
1/100	4	2	6 2/3	6.12
1/50	4	4	13 1/3	5.10
1/33	4	6	20	4.86
1/25	4	8	26 2/3	4.83
1/20	4	10	33	5.02
1/100	8	1	3 1/3	4.16
1/50	8	2	6 2/3	4.39
1/25	8	4	13 1/3	3.42
1/16	8	6	20	2.73
1/12	8	8	26 2/3	2.99
1/10	8	10	33	2.96
1/50	16	1	3 1/3	4.38
1/25	16	2	6 2/3	4.07
1/12	16	4	13 1/3	2.93
1/8	16	6	20	2.59
1/6	16	8	26 2/3	2.68
¼	16	12	40	2.10

EFFECT OF SHAPE OF PLAT ON PROBABLE ERROR

Probable errors of plats of the same size but of different shape are presented in Table 2. The most satisfactory length for a plat appears to be about 8 rods. Moreover, long narrow plats are more convenient to harvest than square plats and are almost universally used in sorghum varietal testing. The probable errors are slightly less for long narrow plats than for those more nearly square in shape. In a field of level or nearly level contour, soil heterogeneity is likely to be more evident in small spots or areas than by progressive variation.

TABLE 2.—*Probable errors of the yields of plats of the same area but of different shapes.*

Approximate size of plat (acre)	Dimensions of plat			Probable error of yields of single plats (bushels per acre)
	Length in rods	No. of rows	Width in feet	
1/100	2	4	13 1/3	5.82
	4	2	6 2/3	6.12
	8	1	3 1/3	4.16
1/50	2	8	26 2/3	5.46
	4	4	13 1/3	5.10
	8	2	6 2/3	4.39
	16	1	3 1/3	4.38
1/25	4	8	26 2/3	4.83
	8	4	13 1/3	3.42
	16	2	6 2/3	4.07

REDUCTION OF PROBABLE ERROR BY REPLICATION

For the purpose of studying the value of replication, the variability of yield was computed for varying numbers of one to six systematically distributed plats, as shown in Table 3. As expected, the probable error decreased as the number of replications was increased. Even when the combined area of a replicated series of plats was no greater than the area of a single plat, the probable error was materially reduced by replication. As an illustration, the probable error of a single 1/25 acre plat consisting of four contiguous 8-rod rows was 3.42 bushels per acre, while the probable error of four single 8-rod rows systematically distributed was 2.08 bushels per acre, a reduction of 39.2%. Similarly, the probable error of four replications of 2-row plats 8 rods long by 6 2/3 feet wide is 1.39 bushels, while for the same area in two replications of four 8-rod rows the probable error is 2.97 bushels.

Within reasonable limits as to size of plats in a restricted area, the use of a larger number of replications and smaller plats can be expected to reduce the probable error more rapidly than the use of larger plats and fewer replications.

TABLE 3.—*The probable error of Dawn kafir yields as influenced by replication.*

Approximate size of plat	Dimensions of plat				Probable error of yields in bushels per acre with the number of replications indicated					
(acre)	Length in rods	No. of rows		Width in feet	1	2	3	4	5	6
1/400	2	1	3	1/3	7.57	5.64	3.79	4.53	2.79	2.44
1/100	2	4	13	1/3	5.82	4.40	2.26	3.25	3.32	1.47
1/50	2	8	26	2/3	5.46	3.82	1.98	2.99	2.79	1.21
1/200	4	1	3	1/3	6.59	4.88	3.67	3.96	2.29	1.98
1/100	4	2	6	2/3	6.11	4.49	3.45	3.59	2.08	1.21
1/50	4	4	13	1/3	5.10	3.31	2.55	2.69	1.50	0.81
1/100	8	1	3	1/3	4.16	3.91	2.43	2.08	1.66	1.06
1/50	8	2	6	2/3	4.38	3.79	1.60	1.39	1.57	0.05
1/25	8	4	13	1/3	3.42	2.97	2.08	0.85	1.06	0.64
1/12	8	8	26	2/3	2.99	2.79	0.05	1.67	—	—
1/10	8	10	33		2.96	2.79	1.17	0.67	0.02	—
1/50	16	1	3	1/3	4.38	2.63	2.20	2.24	1.04	1.81

The fact should not be overlooked that results recorded in Table 3 can be obtained only when the same area of land is used as a basis for all calculations, and the results may not be applicable to another set of conditions. With such crops as sorghums, when border rows are used, the additional land required is often increased from one-third to one-half. When such additional land is required for this or other reasons, the larger area taken into the experimental block increases the chances of encountering more variable land. Large areas of uniform land usually are not available. The cost of conducting an experiment and the opportunity for mechanical errors of various sorts also are increased with replication. Therefore, in practice, the number of replications usually is less than the results in Table 3 indicate as being desirable.

In connection with the study of replicating plats to correct for soil heterogeneity, consideration must be given to the fact that climatic variations from year to year are very great in the Plains region. The standard deviations in yields for the several major crops at the Hays station are greater than the mean yields for the same crops over a period of years. The variations in yield from one season as compared to another have been known to fluctuate from 0 to 65 bushels per acre for an adapted variety of sorghum. Still more disturbing is the order in which varieties are influenced by seasonal variation. The need of sampling the seasons over a period of years is as important as providing means for correcting errors due to soil heterogeneity. The magnitude of error from seasonal variation has been pointed out by Engledow and Yule (1) and by Stadler (2).

Perhaps the chief causes for variations in sorghum yields under a given set of conditions, in addition to soil heterogeneity and environ-

ment, are uneven stands and disturbances from methods of cultivation. The sorghum plants are delicate and slow growing in the early stages of growth. Replication is desirable, therefore, because it is sometimes necessary to discard a plat having a poor stand or because the plants have been injured or destroyed by mechanical or uncontrolled causes.

Sorghum plants are larger and require more space than plants of small grains and larger plats usually have been considered necessary. Results here obtained indicate that grain sorghums require about the same number and size of plats as other field crops for dependable experimental results.

SUMMARY

The reduction in probable error of grain sorghum yields is not great after the plat has been increased in size to 1/25 acre. Long narrow plats seem the most reliable for varietal trials and certainly are the most practical from the standpoint of economy. The probable error is slightly lower for long narrow plats than for square plats of the same area. When protected by borders, 2- to 4-row plats 8 rods long having an area from 1/50 to 1/25 acre are desirable and convenient units.

Since the average yields of grain sorghums on the field stations in the Great Plains are less than 30 bushels per acre, two to four replications of a variety should usually reduce the probable error to 1 to 3 bushels per acre when 1/50 to 1/25 acre plats are used. For dependable results, it is also necessary to grow varieties for a sufficient number of years to sample the seasons which vary greatly in the Great Plains area.

LITERATURE CITED

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