Objective Yield Techniques for Estimating Grain Sorghum Yields

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CONTENTS

Introduction

The Statistical Reporting Service sponsored grain sorghum research by Iowa State University during 1959-64. A separate study was conducted in Oklahoma in 1964. The purpose of these projects was to examine growth patterns that could be used as yield indicators in an objective yield survey.

Additional research was conducted in 1969 in Kansas and Texas. Here, the primary goal was to obtain experience dealing with some of the problems encountered in the earlier studies.

This report summarizes the major findings of the Iowa and Oklahoma studies. Then it documents procedures followed and data collected from the Kansas and Texas studies in 1969. Some analysis is shown along with suggestions for additional research.

Summary of Previous Research

Iowa State University Research, 1959-64

The item given primary consideration during the first three years was the determination of an optimum sampling design for estimating dry kernel weight. The results follow:

1. 1959 - The optimum plot size was three rows wide by 80 feet long. Two plots within each sample field should be selected. The optimum number of sorghum heads to select from each plot was 7.

2. 1960 - The optimum plot size for completely harvesting the plots was determined. It was two rows wide by 4 feet long.

3. 1961 - The optimum sample design for each sample field was 5 plots, each one row wide by 10 feet long. Three sample heads per plot should be selected.

The optimum sampling rates determined each year differ considerably. This was effected somewhat by variable growing conditions between the years and differences in the number of sample fields. The cost and variance functions used each year also contributed to the variability between years.

The estimated number of kernels per head was obtained by visually comparing the sample head with another head for which the kernel count was known. This was a subjective procedure and was not very precise. The actual count of kernels per head was found to be correlated with final yield. However, they experienced difficulties in finding a counting procedure that was both accurate and efficient.

In 1961, several plant characteristics were examined to determine their relationship with final yield. The observations were made in August and September. These were then correlated with the dry kernel weight per head at harvest time. The results appear in Table 1.

Table 2 contains the correlations for some additional variables that were also observed in 1962 and 1963.

In 1960 and 1963, gleaning operations were conducted to measure harvesting losses. The estimated average loss per acre represented 8.0 percent of the total biological yield per acre in 1960 and 5.4 percent in 1963. Loose kernels contributed 24 percent of the amount left in 1960 and 34 percent in 1963. It was time consuming and costly to pick up the loose kernels by hand. An alternate procedure tried was to use a broom to gather the kernels and then a sieve to separate the kernels. This procedure was not very successful.

Table 1.--Correlation coefficients between harvest weight per sorghum head and observations made on sample plants, Iowa, 1961.

Variable	August (r)	September (r)
Plant height	.42	.38
Stem diameter at plant base	.75	.68
Stem diameter at head base	.41	.53
Head length	-.35	-.59
Head circumference	.40	.49
Eye estimate No. branches in head	.39	.46
Eye estimate No. kernels in head	.57	.23
Number plants in row	-.34	-.33
Number heads in row	.02	.31

Table 2.--Correlation coefficients between harvest weight and observed variables, Iowa, 1961, 1962, and 1963.

Variable	1961	1962	1963
August plants per foot	-.3994	.6650	-.7234
August % heads	.4244	.4243	.3467
August DKW* per head	.5167	.6310	.4445
August % dry matter	.2746	.3476	-.0324
August DKW X % dry matter	.4222	.6289	.3414
September heads per foot	-.3820	-.5547	-.7641
September DKW per head	.7198	.7593	.7449
September % dry matter	.2025	.3098	.0995
September DKW X % dry matter	.6071	.7082	.6697

* Dry kernel weight

Oklahoma Research - 1964

The length of the head and the diameter of the culm (stem) at the base of the head appeared to be the best plant characteristics to be used. The relationship of number of kernels per head to total head weight was very good. However, the number of kernels per head was difficult to obtain.

The optimum plot size was found to be two rows wide by five feet long. The optimum number of plots to sample within a field was one.

Texas and Kansas Studies - 1969

I. Sample Selection

A. Texas

Sorghum heads were randomly selected from several sample units laid out for a remote sensing study in the lower Rio Grande Valley. Sample heads were clipped at two different times - once in the flower stage of development in June, 1969 again in the hard dough stage in July, 1969.

B. Kansas

Fields were subjectively selected in four counties. Heads were clipped from each field during regular SSO field travel in July and August, 1969.

II. Laboratory Procedures:

A. Texas Samples

The following measurements were obtained for all sample heads in both growth stages:

(1) Weight of head (air dried).

(2) Diameter of culm one inch below base of head.

(3) Length of head from the lowest node to tip.

A total of 10 heads were clipped from plants in the flowering stage When fields reached the hard dough stage, 199 heads were clipped.

Additional observations were made on the 10 heads from the first sample and a subsample of 20 heads from the second sample. They were:

(1) The number of nodes on a head.

(2) The number of branches on each node.

(3) The number of spikelets on each branch.

(4) The number of kernels in spikelets of two selected branches.

The twenty heads from the second sample were threshed in a mechanical harvestor (similar to that used in wheat objective yield surveys). A count of threshed kernels was obtained.

B. Kansas Samples

Similar observations were made on the 110 heads collected in Kansas. They were:

(1) Dry head weight.

(2) Length of head.

(3) Head width at mid-point.

(4) Diameter of culm.

Unfortunately the monthly samples were not identified by the date they were clipped. Thus, it was not possible to analyze the data separately by month.

III. Analysis:

A large part of the analysis consisted of computing correlations between the variables observed. The relationships found may not necessarily hold over the season. For example, culm diameter may be correlated with head weight when it is in the hard dough stage. However, the relationship between the culm diameter at the flowering stage and the head weight at maturity is more important for forecasting purposes. This report will not answer all such questions. The data may prove helpful if additional research is to be conducted.

The data was analyzed separately by state with emphasis on the Texas observations.

A. Texas

The first items computed were the simple correlation coefficients between several variables and head weight at the time of the observation. The inter-correlations between the observed variables were also computed. These will help determine which variables that are correlated with weight may also be highly correlated with each other making it necessary to measure only one of them.

The following tables present the basic data:

Table 3.--Matrix of simple correlation coefficients between selected variables, grain sorghum in flower stage, Texas, June, 1969

Variable	Dry head wt.	Head length	Culm diameter
Dry head weight	----	.89	.61
Head length	----	---	.64
Culm diameter	----	---	---

For 10 observations
A correlation of r > .77 is significant at the 01% probability level.
A correlation of r > .63 is significant at the 05% probability level.

Table 4.--Matrix of simple correlation coefficients between selected variables, grain sorghum in hard dough stage, July, 1969

Variable	(1)	(2)	(3)	(4)	(5)	(6)
(1) Dry head weight	---	.82	.60	.84	.82	.83
(2) Culm diameter		---	.73	.98	.97	.96
(3) Head length			---	.66	.84	.72
(4) Culm C.S.A.				---	.95	.99
(5) Culm circumference x head length					---	.97
(6) Culm C.S.A. x head length						---

For 199 observations, a correlation coefficient of .18 is significant at the 01 percent probability level, and a coefficient of .14 is significant at the 05 percent probability level.

The correlations did not remain very consistent over the two time periods. However, the sample sizes differed considerably and the observations were on different plants.

Research has shown that an early season count of kernels is correlated with grain weight at harvest time. To gain experience with laboratory procedures, detailed counts of nodes, branches, spikelets, and kernels were made on all plants selected in the flower stage and on a subsample of those collected in the hard dough growth stage.

The basic data is summarized in Tables 5 and 6. In order to obtain these counts it was necessary to clip the branches from the nodes. Thus, it would not be possible to obtain these observations in the field. The number of minutes it took to analyze each head is also shown. It appears that a subsampling scheme will be necessary to reduce the time.

The next item examined was the distribution of kernels in the sorghum head. A nested analysis of variance was computed for each set of data. The results appear in Tables 7 and 8. It can be concluded that:

(1) Within a node, every branch has about the same number of kernels per spikelet.

(2) Within a plant, every node has about the same number of kernels per spikelet.

(3) There is a significant difference between heads.

The variance components indicate it would be sufficient to count the kernels on one branch from one node in each head to estimate the number of kernels per head. It would still be necessary to count the number of nodes and the number of branches on the selected node.

Table 5.--Counts obtained from selected sorghum heads in flower stage, Texas, June, 1969

Plant	Number of nodes	Number of branches	Number of spikelets	Minutes to count nodes etc.
1	13	54	459	80
2	16	44	164	29
3	11	54	422	59
4	13	51	419	86
5	10	45	320	53
6	11	47	425	54
7	11	48	383	107
8	11	53	363	66
9	13	55	234	69

Table 6.--Counts obtained from selected sorghum heads in hard dough stage, Texas, July, 1969

Plant	Number of nodes	Number of branches	Number of spikelets	Minutes to count nodes etc.
1	11	55	355	32
2	11	51	316	31
3	12	52	360	54
4	8	56	826	67
5	11	40	114	16
6	9	54	838	70
7	10	54	428	31
8	10	53	812	120
9	9	68	1244	110
10	10	55	648	59
11	11	56	384	38
12	10	57	404	60
13	8	51	258	27
14	14	54	283	49
15	10	33	137	17
16	11	41	133	73
17	12	41	159	31
18	11	38	152	28
19	12	45	250	44
20	11	46	199	30

Table 7.--Analysis of variance on observations made on sorghum heads, flower stage, Texas, 1969

Source of variation	D.F.	Mean square	F	Variance components
Between heads	22	8.28	6.05**	.479
Between nodes/plants head	220	1.37	1.42	.313
Between branches/nodes	238	.96	.92	-.125
Between spikelets/branches	2802	1.05		1.050
Mean = 3.08 = average number of kernels per spikelet.				

** Significant at the 01 percent level of probability.

Table 8.--Analysis of variance on observations made on sorghum head, hard dough stage, July, Texas, 1969

Source of variation	D.F.	Mean square	F	Variance components
Between heads	8	7.65	3.11**	.305
Between nodes/heads	100	2.46	1.02	.265
Between branches/nodes	100	2.42	1.11	.033
Between spikelets/branches	1306	2.18		2.18
Mean = 3.26 = average number of kernels per spikelet.				

** Significant at the 01 percent level of probability.

The sorghum heads in the hard dough stage were then threshed in a mechanical thresher.[1/] Heads in the flower stage were not threshed as the kernels were not developed enough to be separated from the chaff.

The threshed kernels were counted and weighed. The time spent on each step was also obtained. The observations are summarized in Table 9. Some difficulties were encountered.

(1) The branches had to be clipped from the nodes and separated into two or three groups because the machine available would not handle the entire head.

(2) The machine shattered many kernels - thus, causing a counting problem.

(3) The chaff did not separate very well - considerable hand sorting was necessary.

The time required to count the kernels was also lengthy. The use of the mechanical thresher does not seem warranted for two reasons:

(1) The number of kernels per head can be determined early in the head development. This is probably when the information in needed in a forecasting model. However, at this stage, it will be necessary to count or estimate the number of kernels on the head because they cannot be mechanically threshed.

(2) A subsampling procedure would probably be less time consuming

Some additional correlations were computed for the heads in the hard dough stage. They are shown in Table 10. If these relationships remained consistent until harvest time, they would be good forecast indicators.

1/ The machine is commonly referred to as the "micro thresher" developed for the wheat objective yield survey laboratory procedures in the State Statistical Offices. It is basically a blender that breaks up the head and a vacuum to remove the chaff.

B. Kansas

Simple correlation coefficients were computed for the variables measured. No real inferences can be made because the data represent several different samples, that is, heads selected in different months. They do give some basis for comparing the growth characteristics. The sample was not collected in a manner to allow any further analysis.

The correlation matrix is shown in Table 11.

Table 9.--Observations made on threshed grain sorghum heads in hard dough stage, Texas, July, 1969

Plant	Number of whole kernels	Weight of damaged kernels (grams)	Weight whole and damaged kernels (grams)	Minutes to thresh	Minutes to count
1	1011	.3	16.2	30	32
2	714	1.4	13.6	30	38
3	816	.3	15.4	37	45
4	2043	2.1	39.1	55	130
5	18	.2	.5	5	3
6	2180	1.0	42.6	84	70
7	1154	.3	24.4	5	30
8	1101	.3	32.7	20	28
9	2807	.6	86.8	22	58
10	2012	.3	50.6	--	31
11	740	3.1	27.4	17	60
12	1124	.4	29.8	31	26
13	664	.2	12.2	20	18
14	857	.1	19.7	10	20
15	386	0	12.0	5	7
16	308	.1	18.4	12	37
17	506	0	13.7	20	17
18	0	0	0	--	--
19	639	.9	14.8	15	20
20	44	0	.5	10	10

Table 10.--Correlation coefficient between weight of all kernels and observations made on grain sorghum head in hard dough growth stage, Texas, July, 1969

Variable	Correlations with weight of kernels	Means of variable
No. of kernels	.924	1060 kernels per head
No. of nodes	.449	10.6 nodes per head
No. of branches	.766	50.0 branches per head
No. of spikelets	.918	415 spikelets per head
Ave. wt. of kernels per head	----	23.5 grams

For 20 observations, a coefficient of .56 is significant at the 01 percent probability level, and a coefficient of .44 is significant at the 05 percent probability level.

Table 11.--Matrix of simple correlation coefficients between selected variables, grain sorghum, Kansas, 1969

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Dry head weight	---	.21	.75	.42	.18	.64	.43
(2) Head length		---	.22	.43	.99	.17	.40
(3) Head width			---	.54	.21	.95	.54
(4) Culm diameter				---	.43	.53	.98
(5) Length squared					---	.16	.40
(6) Width squared						---	.55
(7) Diameter squared							---

110 observations.

IV. Summary:

The results showed that the actual number of kernels in a sorghum head is highly correlated with the head weight. However, it was difficult and time consuming to obtain these counts. Even if a better procedure for threshing the heads is devised, it still would take considerable time to do the counting.

A reasonable alternative would be to estimate the number of kernels. The number of nodes and branches within nodes can be counted easily and quickly. The number of kernels in a small subsample of branches may provide a fairly precise estimate.

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APPENDIX

Form I

July 1969 Texas Sorghum Head LAB Measurements and Weights

Head No. _____ _____ _____ _____
Flight line (Field) (Unit) (Head)

1. Diameter of culm (measured 1 inch below node where) ____.____(1/32 inch)
2. Length of head (measure from node where first branches emerge to tip of head) ..... ____.____(1/10 inch)
3. Weight of dry head (after cutting head stalk 1 inch below node where first branches emerge)... ____.____(1/10 grams)

* If the unit number is even (2, 4, 6, or 8), complete counts on Branches, spikelets, and kernels and record on count form.

Instruction for Measuring 1969 Kansas Sorghum Heads

1. Each bag contains several sorghum heads. Remove from bag and separate them carefully so that no stems are broken.
2. Weigh head - record to 1/10 gram.
3. Measure length of head from lowest node to tip.
4. Measure width at mid-point of head.
5. Measure diameter of culm approximately one inch below lowest node.
6. After measuring all heads from a bag replace them. Be sure that identification slips are replaced also.

Record data to one decimal place.

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Sorghum Threshing and Counting Instructions

A. Threshing

1. The only information that needs to be recorded is the starting and ending time.
2. Clip spikelets from head using scissors. Divide the spikelets in three equal size piles - thresh each separately.
3. After threshing each group - remove chaff and check it for unthreshed kernels.
4. Put kernels back into original bag - throw chaff away.

B. Hand Count

1. Count number of whole kernels using hand counter.
2. Count number of cracked kernels and loose pieces.
3. Be sure to enter starting and ending times.

July 1969 Texas Sorghum
Lab Counts

Head _____

Number of Branches on Node 17 _____

. Number of Spikelets on Branch:

1. _____	4. _____	7. _____
2. _____	5. _____	8. _____
3. _____	6. _____	9. _____

..Number of kernels in Spikelets of two selected Branches:

Branch _____ Branch _____

Spikelet		Spikelet	
1.	_____ 2/	1.	_____
2.	_____	2.	_____
3.	_____	3.	_____
4.	_____	4.	_____
5.	_____	5.	_____
6.	_____	6.	_____
7.	_____	7.	_____
8.	_____	8.	_____

Head _____ Starting Time _____

Number of Branches on Node _____

. Number of Spikelets on Branch:

1. _____	4. _____	7. _____
2. _____	5. _____	8. _____
3. _____	6. _____	9. _____

..Number of kernels in Spikelets of two selected Branches:

Branch _____ Branch _____

Spikelet		Spikelet	
1.	_____	1.	_____
2.	_____	2.	_____
3.	_____	3.	_____
4.	_____	4.	_____
5.	_____	5.	_____
6.	_____	6.	_____
7.	_____	7.	_____
8.	_____	8.	_____

Number of Branches on Node _____

. Number of Spikelets on Branch:

1. _____	4. _____	7. _____
2. _____	5. _____	8. _____
3. _____	6. _____	9. _____

..Number of kernels in Spikelets of two selected Branches:

Branch _____ Branch _____

Spikelet		Spikelet	
1.	_____	1.	_____
2.	_____	2.	_____
3.	_____	3.	_____
4.	_____	4.	_____
5.	_____	5.	_____
6.	_____	6.	_____
7.	_____	7.	_____
8.	_____	8.	_____

Head _____ Starting Time _____

Number of Branches on Node _____

. Number of Spikelets on Branch:

1. _____	4. _____	7. _____
2. _____	5. _____	8. _____
3. _____	6. _____	9. _____

..Number of kernels in Spikelets of two selected Branches:

Branch _____ Branch _____

Spikelet		Spikelet	
1.	_____	1.	_____
2.	_____	2.	_____
3.	_____	3.	_____
4.	_____	4.	_____
5.	_____	5.	_____
6.	_____	6.	_____
7.	_____	7.	_____
8.	_____	8.	_____

1/ Node 1 is the node nearest the base of the head.
2/ Spikelet 1 is the spikelet nearest the main stalk of the head.