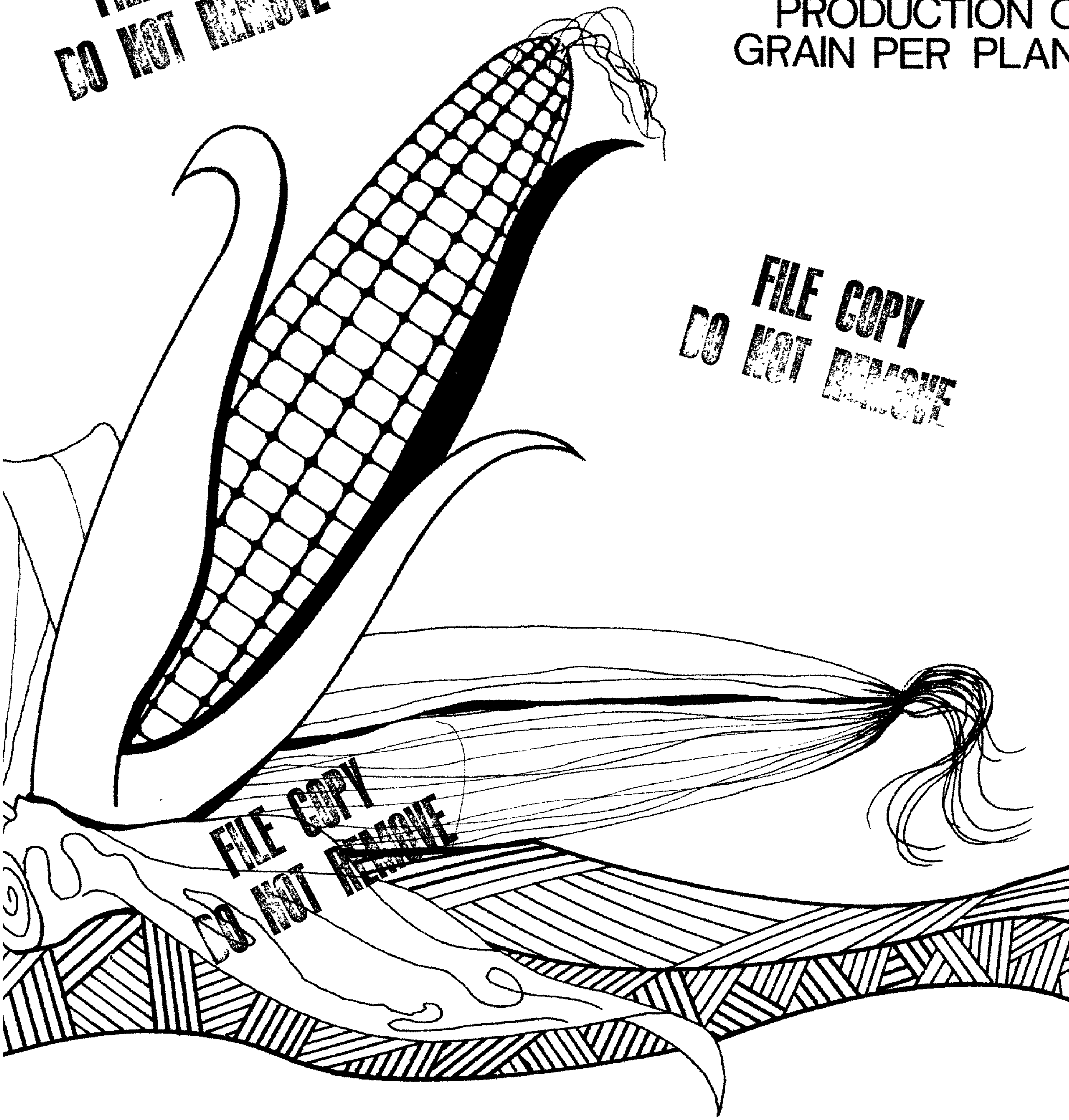
USING CORN PLANT VEGETATIVE CHARACTERISTICS TO FORECAST PRODUCTION OF GRAIN PER PLANT



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SUMMARY

Recent experiments show that corn plant vegetative characteristics (plant height, leaf area, node count, etc.) are useful in making early season forecasts of ultimate production of grain per plant.

Several such early season indicators proved as effective in forecasting final grain weight as kernel counts and ear measurements--which can only be made much later in the crop year. The field experiments were made in Howard County, Maryland, during the 1969 crop year; the soil and leaf samples were analyzed in the Soils Laboratory of the University of Maryland.

While the use of vegetative characteristics is considered useful and promising as early season indicators, they cannot yet be used reliably in forecasting models because of the limited time span covered by such investigations.

USING CORN PLANT VEGETATIVE CHARACTERISTICS TO FORECAST PRODUCTION OF GRAIN PER PLANT

by

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INTRODUCTION

A major problem in the development of corn yield forecasting models has been predicting the weight of grain per ear at maturity for immature plants. Currently, predictions on August 1 are made only for sample fields with ear sets that are in the blister stage of development. In general, more than 90 percent of the corn fields in the Corn Belt States have not reached this stage of maturity by the last week of July when survey data for the August 1 crop report are collected. Therefore, the predicted ear weight is based upon historic averages.

This study describes results obtained for ten sample plots located in five fields for the 1969 crop year. Its purpose was to examine vegetative characteristics that might be used as early season indicators of final grain weight in larger research studies in the future. The main interest was in fields with plants not having ear shoots or ears developed to the blister stage. Some consideration was given to development of improved techniques for estimating ear weight using kernel counts for later stages of development. Studies at Iowa State University (1951-61) showed that these counts could be obtained about mid-August and were useful in forecasting ear weight.

A kernel-counting procedure was implemented in the laboratory analysis to gain experience in dealing with some of the problems that would be encountered. The counts for current work were obtained from ears from mature plants, therefore, not all the relationships considered in the Iowa study could be compared in this study.

FIELD PROCEDURES

Five fields were selected in Howard County, Md. They were selected to represent a range of planting dates and growing conditions. To further increase the amount of variability in the sample, observations were taken on plants in one of the "best" and in one of the "worst" rows in each field.

Observations were obtained weekly on the 5th, 15th, 25th, 35th, and 45th plant in each selected row. The first measurements were taken in the period July 23/24. The same measurements were obtained at weekly intervals through August 12/13. The instructions followed for the field procedures are in the appendix.

The following are measurements, counts, and observations made in sample fields.

A. Information collected only on first visit:

1. Soil sample adjacent to each sample plant

2. Leaf sample from plants adjacent to the sample plants taken to test for nutrients present

3. Variety and planting dates

4. Type, amount, and timing of fertilizer applications

B. Weekly observations made on all sample plants:

1. Presence or absence of tassel

2. Height of plant - from ground to highest node

3. Number of nodes (excluding basal node).

4. Observations made on each node:

    a. Length of leaf

    b. Width of leaf at midpoint

    c. Maturity category of ear emerging from node (if any)

5. The diameter and circumference of every third internode beginning with a random start

6. Number of leaves in the whorl.

Plants were classified by their stage of development during each weekly visit. Portions of the classification criteria used in the regular objective yield survey could not be applied. They would have required removing portions of the husk - thus affecting the development of the ear. Table 1 gives the maturity codes and their comparisons with the objective yield criteria.

At harvest time ears were removed from the sample plants. One field had been cut for silage, leaving only 40 plants to be harvested.

Table 1.--Maturity codes, corn vegetative characteristic study, Howard County, Md., 1969

Code	Vegetative characteristic criteria	Objective yield classification
0	(a) Tassel has not emerged. (b) Tassel emerged.	No ears or shoots present
1	Ear shoot emerged - no silk showing.	Ears not formed
2	Silk showing - no kernel formation.	Preblister
3	Silk turning brown and dry. Presence of developing kernels can be felt through husk.	Blister
4	Silk brown and dry. Plants and husks are green. Ears are erect.	Milk
5	Husks turning rust colored. Ears leaning away from stalk.	Dough
6	Husks about dry - pulling away from ear. Ear is solid and firm.	Dent

LABORATORY PROCEDURES

The soil and leaf tissue samples were analyzed by the Soils Laboratory of the University of Maryland. Tests conducted on the leaf tissues determined the proportion of phosphorus, potash, calcium, and magnesium present. The soil samples were analyzed to determine the levels of P^H, magnesium, phosphate, potash, and organic matter.

The harvested ears were dried and weighed. Several other observations were made on the harvested ears to determine their relationship with grain weight:

A. Length of cob

B. Length of longest kernel row

C. Circumference at midpoint of cob

D. Number of kernel rows

E. Number of kernels in two systematically selected rows

F. Ear weight

G. Number of weight of shelled kernels:

1. Number and weight of whole kernels

2. Number and weight of damaged kernels

3. Number and weight of immature kernels.

Instructions followed in the laboratory procedures are presented in the appendix.

DATA ANALYSES

The primary objective of this study was to examine the growth characteristics of corn plants and determine their relationship with final grain weight. Most of the analysis consisted of comparing the correlation coefficients between the observed variables and final grain weight. Since the selected fields and sample rows were subjectively chosen, e.g., "best" and "worst" rows, the data show more variability than would probably be present in a random sample. Therefore, the nonrandom nature of the sample should be kept in mind when comparing the significance tests, etc.

Data collected in weeks one and two fall in the general time periods when the regular August 1 forecast survey is underway. The main emphasis will be on these data. The information was collected for the additional weeks to determine whether the relationships remained consistent over time as maturity categories change.

Field Observations

The measurements of each leaf (length and width) were used to obtain an approximation of leaf area. The means and respective correlations of these variables with final grain weight were computed. Correlations for several combinations of leaf areas were computed, e.g., areas for leaves one through seven vs. grain weight. Similar computations were obtained for the diameter and circumference measurements.

The plants were classified by maturity category each week; means and correlations were again computed. This was to determine whether the data behave differently within the different stages of growth. The basic data are presented in the tables 2-6.

Figure 1 indicates the average leaf area shows very little change from week to week. The differences between weeks can be explained by measurement errors. Although the plants showed considerable growth during the four-week period as shown by the increase in height in figure 2, the stability of the leaf area indicates that repeated measurements would not be necessary.

When the size data are separated into maturity categories, less stability is present because the plants change their classification from week to week.

The tables indicate several variables that are highly correlated with final grain weight. The performance of these variables remains reasonably consistent for different maturity categories during different weeks. For example, the area of the leaf on node seven generally shows the largest correlation with final yield. This variable is also usually the "best" when dividing the data into maturity categories.

There are other variables that are also highly correlated with final ear weight. One phase of the analysis was to determine the "best" subset of variables for predicting final weight. The first step was to determine whether it is necessary to classify the plants by maturity category and have a prediction equation for each.

Table 2.--Stage of development of sample plants by date of observation, corn, Howard County, Md., 1969

Stage	Number of plants			
	Week 1 July 23-24	Week 2 July 30-31	Week 3 Aug. 6-7	Week 4 Aug. 12-13
	No ear shoots present			
Pretassel.......	16	5		
Tassel..........	5	4	2	
	Ears or ear shoots are present			
Silk not emerged	5	5	2	1
Pretassel.......	14	13	6	5
Blister.........	0	13	18	10
Milk............	0		12	24
Total	40	40	40	40

Table 3.--Means of variables and their correlations with final grain weight, corn, Howard County, Md., week 1, July 23, 24, 1969

Variable	All plants		Maturity 0		Maturity 1		Maturity 2		No tassel		Tassel emerged	
	Mean	r	Mean	r	Mean	r	Mean	r	Mean	r	Mean	r
Cob length	0.2	.15	-----	----	-----	----	0.6	.07	-----	----	0.4	.12
Basal area (0)	6.4	.90	4.4	-.90	4.1	-.34	10.1	.10	5.8	.70	6.8	.13
Area of leaf (1)	33.2	.44	26.9	.40	14.0	-.48	49.5	.46	27.2	.54	37.2	.41
Area of leaf (2)	67.2	.65	56.6	.60	48.9	.27	89.6	.50	54.7	.64	75.5	.58
Area of leaf (3)	101.4	.76	85.6	.65	92.7	.61	128.0	.63	82.7	.68	113.9	.69
Area of leaf (4)	123.0	.76	107.8	.71	120.4	.75	146.8	.49	103.1	.73	136.3	.62
Area of leaf (5)	137.0	.78	119.6	.74	136.2	.94	163.4	.53	112.5	.73	153.4	.70
Area of leaf (6)	141.7	.85	118.8	.83	147.7	.95	173.9	.52	109.4	.83	163.2	.68
Area of leaf (7)	133.5	.90	105.1	.89	145.8	.99	171.7	.67	91.3	.88	161.6	.82
Area of leaf (8)	126.5	.85	99.7	.79	139.8	.91	162.0	.71	86.1	.75	153.5	.82
Area of leaf (9)	111.3	.78	82.1	.66	130.0	.86	148.4	.73	65.6	.54	141.8	.79
Area of leaf (10)	95.1	.81	66.3	.71	117.2	.85	130.4	.79	49.0	.58	125.8	.80
Area of leaf (11)	74.2	.76	49.7	.62	93.0	.72	104.2	.85	31.8	.42	102.4	.76
Area of leaf (12)	56.6	.74	31.9	.58	79.6	.75	85.6	.82	16.2	.31	83.6	.73
Area of leaf (13)	34.6	.55	18.0	.30	62.2	.76	49.6	.64	7.2	-.13	52.9	.56
Area of leaf (14)	13.8	.14	11.1	.14	34.9	.56	10.2	.11	6.6	-.13	18.5	.90
Area of leaf (15)	3.7	.21	3.0	.46	12.4	.28	1.7	-.80	0	0	6.2	.20
Sum 1-6	610.0	.79	519.9	.75	564.2	.63	761.4	.56	-----	----	-----	---
Sum 7-15	649.3	.82	466.9	.73	814.9	.81	863.7	.78	-----	----	-----	---
No. leaves whorl	0.4	-.40	.8	-.30	0	0	0	0	1.1	-.17	0	0
Height	55.9	.77	44.1	.69	62.0	.94	71.5	.20	39.2	.57	67.1	.57
No. nodes	11.7	.62	10.3	.57	13.8	.12	12.8	.49	9.4	.38	13.1	.15
No. leaves measured	11.7	.74	10.3	.74	13.6	.03	13.1	.51	9.3	.59	13.4	.30
No. leaves 0-4	4.0	.14	4.0	.12	3.8	-.43	4.1	.22	4.0	.19	4.0	.19
Largest diameter	1.0	.78	.9	.71	1.1	.53	1.2	.65	.9	.66	1.2	.63
Grain weight (grams)	175.4		128.9		190.7		239.8		105.2		222.3	
No. observations	40		21		5		14		16		24	

Table 4.--Means of variables and their correlations with final grain weight, corn, Howard County, Md., week 2, July 30, 31, 1969

Variable	All plants		Maturity 0		Maturity 1		Maturity 2		Maturity 3	
	Mean	r	Mean	r	Mean	r	Mean	r	Mean	r
Cob length	2.9	.65	-----	---	-----	---	-----	---	9.2	.66
Basal area	5.4	.70	3.7	-.50	3.0	.40	6.3	.30	6.7	.50
Area of leaf (1)	34.5	.39	18.2	-.12	24.1	.91	35.2	.60	48.9	.46
Area of leaf (2)	70.4	.54	53.1	.76	59.6	.56	72.6	.10	84.5	.49
Area of leaf (3)	103.1	.74	69.7	.74	108.8	.21	107.1	.58	120.0	.59
Area of leaf (4)	125.0	.77	85.0	.79	131.3	.10	132.6	.78	142.8	.57
Area of leaf (5)	138.2	.82	100.5	.85	139.2	.10	143.5	.91	158.7	.59
Area of leaf (6)	142.2	.88	105.6	.87	132.2	.37	146.2	.93	167.3	.71
Area of leaf (7)	136.5	.90	101.9	.91	121.7	.47	136.3	.94	166.4	.74
Area of leaf (8)	127.3	.83	87.1	.88	122.2	-.24	125.5	.88	159.0	.74
Area of leaf (9)	116.6	.80	73.8	.85	120.8	-.21	109.3	.86	151.8	.74
Area of leaf (10)	98.7	.77	60.0	.88	107.4	-.21	89.3	.75	131.5	.76
Area of leaf (11)	79.3	.78	40.5	.96	87.8	-.19	72.9	.72	109.2	.82
Area of leaf (12)	57.0	.70	23.7	.91	62.8	-.22	55.0	.67	79.8	.67
Area of leaf (13)	35.4	.57	16.8	.92	39.2	-.27	32.6	.57	49.7	.55
Area of leaf (14)	15.3	.24	9.8	.92	27.0	-.45	12.2	.35	17.6	.15
Area of leaf (15)	4.5	.16	2.9	.63	7.1	-.67	2.5	.31	6.6	.60
Sum 1-6	618.9	.77	435.9	.78	598.2	.60	643.6	.61	728.9	.56
Sum 7-16	670.6	.79	416.6	.94	696.1	-.25	635.6	.78	871.5	.74
No. leaves whorl	0.4	-.54	1.6	-.51	0	0	0	0	0	0
Height	64.3	.60	51.8	.71	58.6	.28	673.0	.77	72.1	.19
No. nodes	13.5	.40	11.1	.77	13.2	-.25	13.2	.18	12.8	.42
No. leaves measured	12.4	.61	9.7	.13	13.0	.04	12.8	.37	13.1	.46
No. leaves 0-4	3.9	.07	3.9	.39	3.8	.46	3.7	-.21	4.0	-.01
Largest diameter	1.0	.78	.7	.49	1.0	-.31	1.1	.54	1.2	.70
Grain weight	175.4		97.7		136.9		183.1		236.3	
No. observations	40		9		5		13		13	

Table 5.--Means of variables and their correlations with final grain weight, corn, Howard County, Md., week 3, August 6, 7, 1969

Variable	All plants		Maturity 3		Maturity 4	
	Mean	r	Mean	r	Mean	r
Cob length	7.5	.66	9.9	.40	10.0	.73
Basal area (0)	1.7	.15	3.7	.27	0	0
Area of leaf (1)	28.2	.33	28.8	.30	32.2	.55
Area of leaf (2)	64.0	.45	71.7	.41	64.5	.52
Area of leaf (3)	102.2	.62	108.4	.66	107.7	.68
Area of leaf (4)	124.4	.71	134.9	.66	133.6	.64
Area of leaf (5)	136.1	.78	145.7	.81	149.5	.61
Area of leaf (6)	138.1	.77	144.0	.65	161.8	.75
Area of leaf (7)	133.4	.81	137.8	.68	162.2	.82
Area of leaf (8)	126.5	.74	123.5	.65	160.6	.79
Area of leaf (9)	117.8	.79	116.9	.75	149.0	.76
Area of leaf (10)	102.2	.77	100.4	.77	137.7	.71
Area of leaf (11)	81.7	.75	75.9	.80	116.1	.65
Area of leaf (12)	62.8	.70	56.6	.72	94.9	.67
Area of leaf (13)	40.0	.56	38.8	.72	58.1	.46
Area of leaf (14)	15.5	.25	17.0	.51	18.7	.90
Area of leaf (15)	3.0	.50	3.0	.36	2.6	.10
Sum 1-6	594.7	.73	637.5	.65	649.5	.78
Sum 7-16	682.9	.76	669.8	.79	899.9	.68
Height	69.2	.51	72.3	.59	69.4	.47
No. nodes	12.7	.54	12.9	.59	13.2	.80
No. leaves measured	12.3	.29	12.0	.33	12.8	.21
No. leaves 0-4	3.6	-.02	3.5	.12	3.5	.46
Largest diameter	1.0	.64	1.0	.68	1.2	-.08
Grain weight	175.4		182.7		236.9	
No. observations	40		18		12	

Table 6.--Means of variables and their correlations with final grain weight, corn, Howard County, Md., week 4, August 12, 13, 1969

Variable	All plants		Maturity 3		Maturity 4	
	Mean	r	Mean	r	Mean	r
Cob length	8.3	.58	10.1	.28	9.4	.15
Basal area (0)	1.6	.15	0	.00	2.6	.14
Area of leaf (1)	19.1	.30	19.4	.90	20.1	.51
Area of leaf (2)	61.5	.61	64.9	.90	65.7	.55
Area of leaf (3)	99.1	.67	90.9	.42	110.5	.65
Area of leaf (4)	123.1	.78	127.2	.67	132.7	.75
Area of leaf (5)	137.7	.78	143.0	.66	148.9	.75
Area of leaf (6)	141.1	.86	145.5	.70	155.7	.84
Area of leaf (7)	136.0	.88	136.5	.74	152.3	.87
Area of leaf (8)	129.4	.79	121.7	.61	145.9	.86
Area of leaf (9)	118.8	.83	112.6	.73	135.3	.86
Area of leaf (10)	103.2	.77	101.1	.66	116.0	.83
Area of leaf (11)	83.7	.74	79.0	.65	95.0	.83
Area of leaf (12)	60.6	.69	54.2	.68	71.5	.72
Area of leaf (13)	35.6	.54	27.6	.71	41.9	.60
Area of leaf (14)	12.9	.21	11.8	.71	13.0	.14
Area of leaf (15)	3.3	.60	2.9	.45	2.6	.11
Sum 1-6	583.2	.78	591.0	.78	636.2	.72
Sum 7-15	683.4	.78	647.4	.74	774.1	.83
Height	69.2	.50	72.1	.53	69.1	.69
No. nodes	12.9	.36	12.8	.65	13.1	.27
No. leaves measured	12.4	.37	12.6	.66	12.5	.40
No. leaves 0-4	3.5	.90	3.6	-.21	3.1	.39
Largest diameter	1.0	.75	1.0	.80	1.1	.61
Grain weight	175.4		165.1		211.0	
No. observations	40		10		24	

FIGURE 1.--AVERAGE LEAF AREA BY WEEK, HOWARD COUNTY, MARYLAND, 1969‡

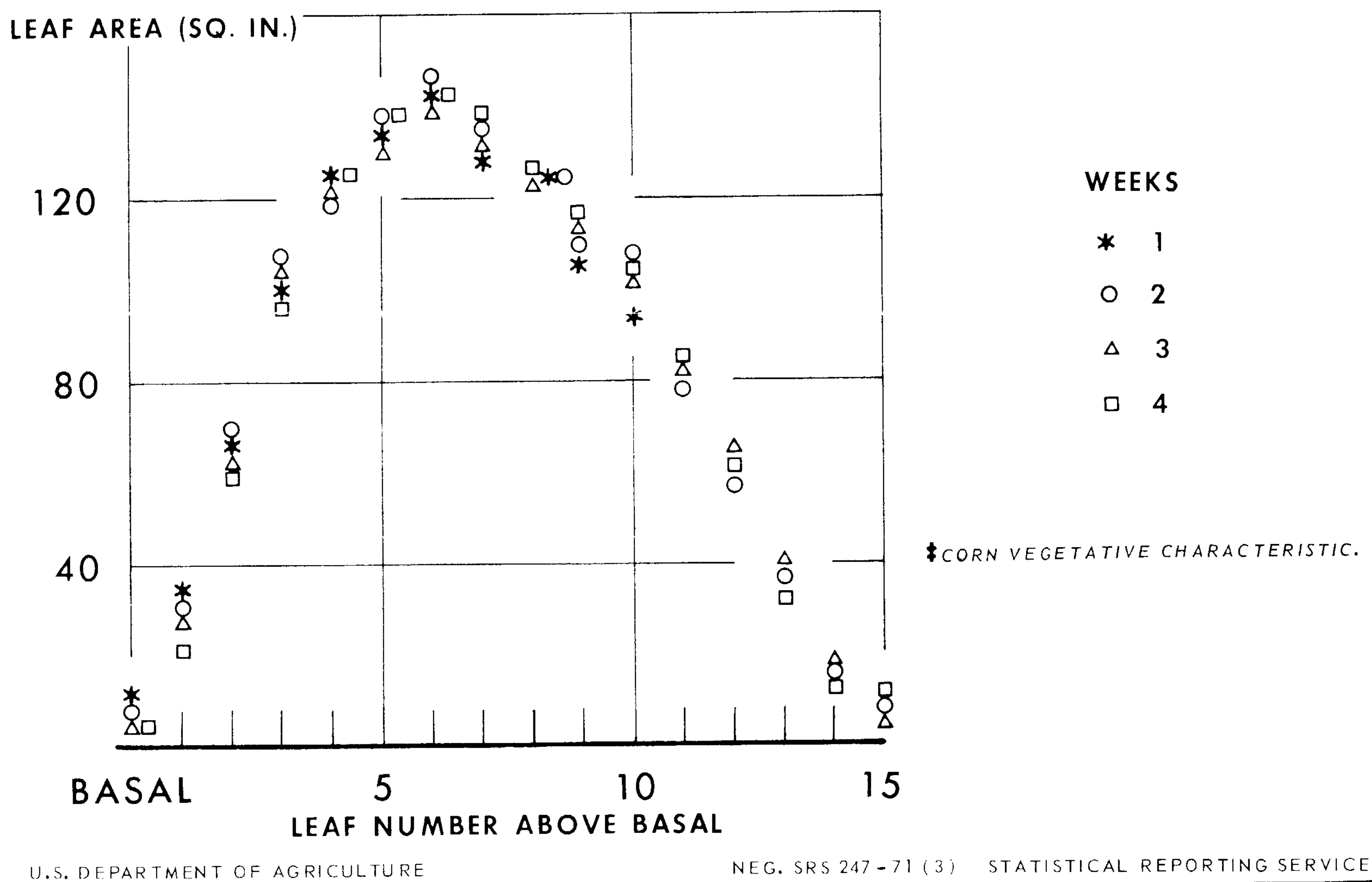
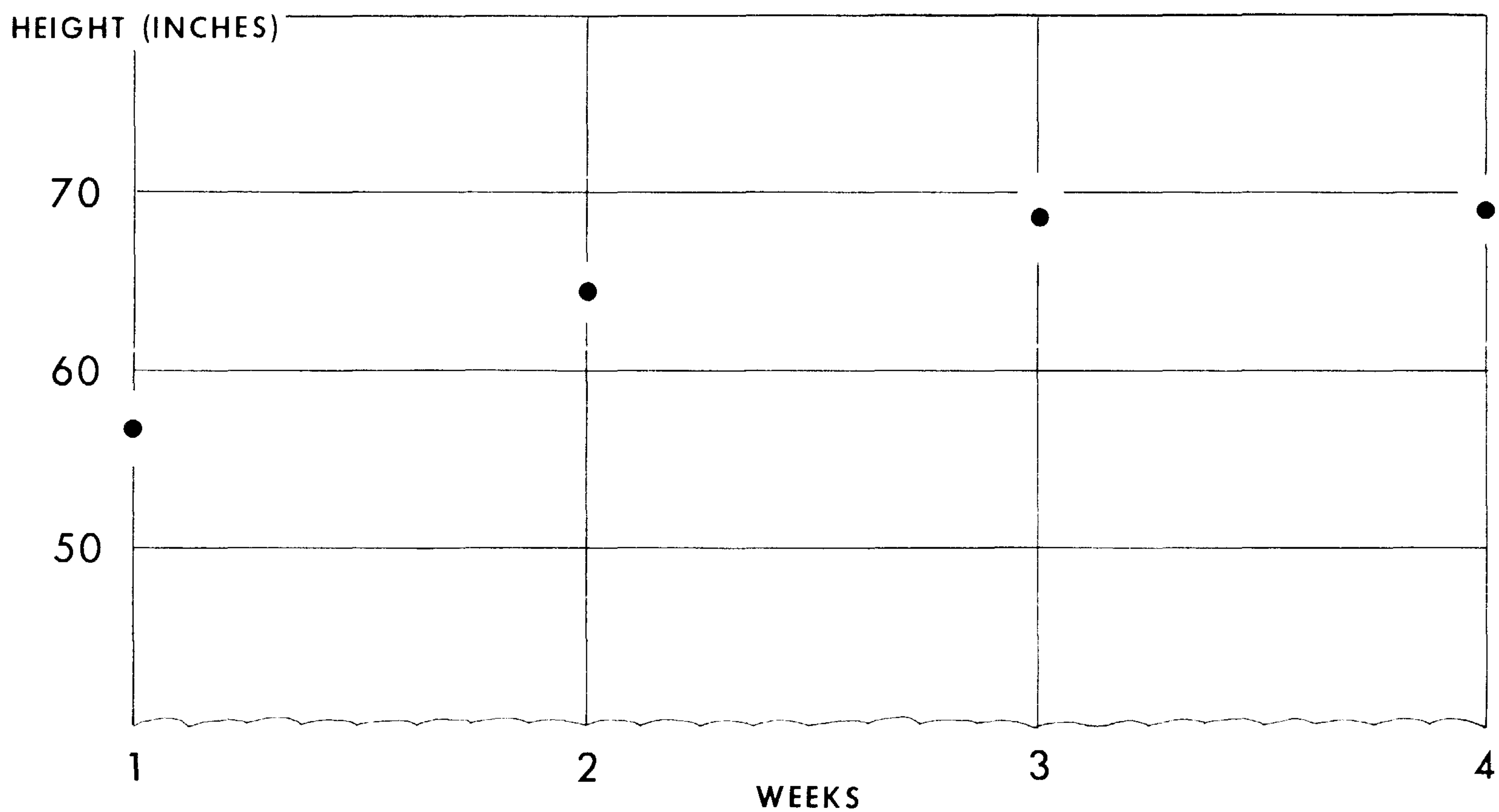


FIGURE 2--AVERAGE PLANT HEIGHT BY WEEK, HOWARD COUNTY, MARYLAND, 1969*



*CORN VEGETATIVE CHARACTERISTIC.

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The first test was on data collected in week one. The test determines the necessity for computing a separate regression for the relationship between final grain weight and the area of leaf seven for maturity categories 0, 1, and 2. The steps are outlined in table 7.

Step (1) tests whether the regression coefficient between X and Y is the same in each maturity category. The F-test is not significant, indicating that the regression coefficients for each category are the same. The usual procedure is to continue testing until a significant result is obtained or until there are no more tests to perform.

Assuming a common slope for all groups, the next step (2) tests whether the intercepts (a_i) differ. The test is not significant, indicating a common intercept. From steps (1) and (2) it is concluded that the data for maturity categories 0 through 3 can pooled.

A final test is necessary to determine whether it is necessary to compute a regression at all step (3). That is, assuming a common intercept and slope, is the regression significant? The conclusion is that the relationship is significant.

The test is repeated for other variables that are closely related to final weight per plant. Then they are repeated for data collected in week two.

The tests for week one data indicate that a common slope and intercept apply for all maturity categories. The data collected in week two still show a common slope, but require different intercepts for the separate categories.

The above tests show the general behavior of the variables. The next question is how the variables behave when they are combined in a multiple regression. Although the data may be pooled when considering each variable separately, this may not hold true in the multiple regression. Additional analysis on this matter is necessary.

A "stepwise" multiple regression procedure was used to obtain the best subset of variables for predicting final yield. The objective is to reduce the number of measurements per plant, but still be able to predict final yield with the required precision. The stepwise procedure chooses the variables that combined give the best estimate. It will not necessarily choose all variables that are highly correlated with yield. This can occur if a high degree of intercorrelation exists between the variables.

Table 7.--Tests of hypothesis about regression coefficients, grain weight vs. area leaf seven, corn, Howard County, Md., week one, 1969

Step	Hypothesis	F-test	Conclusion
(1)	H_o: $\hat{Y}_i = a_i + bx$	0.666	Accept H_o.
	H_a: $\hat{Y}_i = a_i + b_i x$		
(2)	H_o: $\hat{Y}_i = a + bx$	2.562	Accept H_o.
	H_a: $\hat{Y}_i = a_i + bx$		
(3)	H_o: $\hat{Y} = \bar{Y}$	157.637**	Reject H_o.
	H_a: $\hat{Y} = a + bx$		

** Significant at the 99-percent probability level.

Table 8.--Tests of hypothesis about regression coefficients, maturity categories 0, 1, and 2 for week one, corn, Howard County, Md., 1969

Step	Hypothesis	F-test	Conclusion
	-------- Grain weight vs. plant height -------------		
(1)	H_o: $Y_i = a_i + bx$	0.919	Accept H_o.
	H_a: $Y_i = a_i + b_i x$		
(2)	H_o: $Y_i = a + bx$	1.213	Accept H_o.
	H_a: $Y_i = a_i + bx$		
(3)	H_o: $Y = \bar{Y}$	56.100**	Reject H_o.
	H_a: $Y = a + bx$		
	------------- Grain weight vs. stalk diameter -------		
(1)	H_o: $Y_i = a_i + bx$	.278	Accept H_o.
	H_a: $Y_i = a_i + b_i x$		
(2)	H_o: $Y_i = a + bx$	2.914	Accept H_o.
	H_a: $Y_i = a_i + bx$		
(3)	H_o: $Y = \bar{Y}$	59.358**	Reject H_o.
	H_a: $Y = a + bx$		

** Significant at the 99-percent probability level.

Table 9.--Tests of hypothesis about regression coefficients, maturity categories 0, 1, 2, and 4 for week two, corn, Howard County, Md., 1969

Step	Hypothesis	F-test	Conclusion
	---------- Grain weight vs. area leaf ----------		
(1)	H_o: $\hat{Y}_i = a_i + bx$	0.652	Accept H_o.
	H_a: $\hat{Y}_i = a_i + b_i x$		
(2)	H_o: $\hat{Y}_i = a + bx$	3.341*	Reject H_o.
	H_a: $\hat{Y}_i = a_i + bx$		
(3)	H_o: $\hat{Y} = \bar{Y}$	154.640	
	H_a: $\hat{Y} = a + bx$		
	---------- Grain weight vs. plant height ----------		
(1)	H_o: $\hat{Y}_i = a_i + bx$	2.420	Accept H_o.
	H_a: $\hat{Y}_i = a_i + b_i x$		
(2)	H_o: $\hat{Y}_i = a + bx$	9.663**	Reject H_o.
	H_a: $\hat{Y}_i = a_i + bx$		
(3)	H_o: $\hat{Y} = \bar{Y}$	26.797	
	H_a: $\hat{Y} = a + bx$		

* Significant at the 95-percent probability level.
** Significant at the 99-percent probability level.

Table 9.--Tests of hypothesis about regression coefficients, maturity categories 0, 1, 2, and 4 for week two, corn, Howard County, Md., 1969--continued

Step	Hypothesis	F-test	Conclusion
	---------- Grain weight vs. stalk diameter ----------		
(1)	H_o: $\hat{Y}_i = a_i + bx$	1.594	Accept H_o.
	H_a: $\hat{Y}_i = a_i + b_i x$		
(2)	H_o: $\hat{Y}_i = a + bx$	3.972*	Reject H_o.
	H_a: $\hat{Y}_i = a_i + bx$		
(3)	H_o: $\hat{Y} = \bar{Y}$	58.966	
	H_a: $\hat{Y} = a + bx$		

* Significant at the 95-percent probability level.
** Significant at the 99-percent probability level.

Table 10.--Best subset of variables from stepwise procedure, Howard County, Md., 1969

Week 1		Week 2	
Variable	Cumulative multiple correlation	Variable	Cumulative multiple correlation
Area 7th leaf	0.898	Area 7th leaf	0.896
No. leaves in whorl	0.908	Cob length	0.902

Table 10 shows the variables selected by order in the stepwise procedure. The data for all maturity categories were pooled for each week. It seems more feasible to choose the best subset of variables over all maturity categories so that the same data are collected from all plants during a single time period.

Note that after the area of the leaf on the seventh node is considered, the other variables add very little to the regression.

The average time required to obtain all of the measurements on a sample plant was about 10 minutes (9.9). This included time required in getting length and width measurements for as many as 15 leaves and diameter and circumference measurements for three-five internodes. Thus, after selecting and locating a sample plant, additional measurements add relatively little to the total cost. Although the data indicate only two or three variables need be measured, it would be feasible to obtain more that may prove to be useful.

Laboratory Observations

Observations on Harvested Corn Ears

Several different measurements and observations were obtained on the harvested ears. As expected, several of these variables show a high correlation with grain weight. The variables also show a high degree of intercorrelation with each other.

These variables were obtained from harvested ears for which it is not necessary to estimate weight. More important are those variables that could be obtained early in the season and used in a forecast model.

The analysis now indicates that the measurement of some vegetative characteristics may be useful in an early season forecast. The characteristic currently measured in the objective yield surveys is the length of ear over the husk. Not only can the average leaf area be determined earlier in the season, but it also shows a better correlation with grain weight than does cob length measured later in the season.

More analysis is needed to determine whether the variables providing the most information for this data apply in other years and in other producing areas. Additional analysis is also needed to determine how to group the data, i.e., by maturity category, etc.

The kernel row length x midpoint circumference shows the highest correlation with the grain weight. Whether this would hold true earlier in the season remains to be seen. It seems doubtful that these measurements taken when the cobs are small would show similar correlations.

If the estimated number of kernels per ear obtained early in the season remained constant up to harvest time, it would provide a good indicator of yield. The studies conducted at Iowa State showed that it is possible to obtain a good estimate of the number of kernels when the cob is in the "blister" stage.

The data in table 12 show that it is possible to get a good estimate of the total number of kernels from a small sample of kernel rows. (Correlation between estimated total and number counted is 0.96). This is important from an operational standpoint.

Considerable experience was gained in the laboratory procedures in handling problems that could occur in an early season survey.

(a) It was necessary to define a "kernel". The kernels toward the tip of the cob become small and empty. This is mainly caused by poor conditions at pollenating time.

(b) Many ears showed considerable damage caused by insects and/or disease making it difficult to define a kernel.

(c) In many cases it was difficult to determine what constituted a "kernel row" because of the irregular pattern of pollenation.

To obtain the required measurements, the above difficulties required the use of some rather arbitrary definitions (see appendix).

Table 11.--Means, standard deviations, and correlations of observed variables with grain weight, corn, Howard County, Md., 1969

Variable	Mean	Standard deviation	Correlation with weight
Cob length	7.2	1.5	0.88
Kernel row length	6.3	2.3	0.91
Midpoint circumference	5.7	1.6	0.73
No. kernel rows	14.5	4.8	0.61
Kernels in sample row 1	32.8	14.0	0.89
Kernels in sample row 2	32.7	14.4	0.90
No. whole kernels	461.4	217.7	0.85
No. damaged kernels	45.5	54.8	0.42
No. immature kernels	32.0	36.6	-0.19
Row length x circumference	38.9	16.4	0.93
Ave. no. kernels in sample rows x no. rows	514.3	478.0	0.88

r > .39 is significant at the 99-percent level.
r > .30 is significant at the 95-percent level.

Table 12.--Correlations between characteristics of an ear of corn, Howard County, Md., 1969

Variable	Cob length	Kernel row length	Mid-point circum-ference	Number kernel rows	Number kernels sample row 1	Number kernels sample row 2	Number whole kernels	Length x cir-cumfer-ence	Average number kernels in sample row	Esti-mated number kernels	Total weight
Cob length	---										
Kernel row length	.92	---									
Midpoint circum-ference	.64	.80	---								
No. kernel rows	.52	.71	.78	---							
Kernels in sample 1	.83	.90	.75	.69	---						
Kernels in sample 2	.86	.91	.71	.66	.97	---					
No. whole kernels	.79	.83	.71	.72	.92	.91	---				
Length x circumference	.88	.95	.85	.65	.88	.87	.83	---			
Ave. no. kernels in sample row	.85	.91	.73	.68	.99	.99	.92	.88	---		
Estimated no. kernels	.80	.85	.72	.77	.95	.94	.96	.84	.96	---	
Weight	.88	.91	.73	.61	.89	.91	.86	.93	.91	.88	---

Since the length of kernel row shows a higher correlation with ear weight than does the number of kernels, the extra cost incurred in counting or estimating kernels seems unwarranted. Furthermore, some vegetative characteristics showed correlations equally as good as the kernel counts and which can be obtained much earlier.

Soil and Leaf Test Analysis

None of the variables measured in the tests conducted by the University of Maryland showed any relationships with final grain weight. With 40 observations, the lack of correlation cannot be blamed on sample size.

Had the tests showed a significant relationship, the use of the soil and leaf tests would still be fairly impractical in an operational survey because of costs and time required for such measurements. It is doubtful whether the analyses could be completed in sufficient time to use in the forecast.

Recommendations for Further Study

The results for the two years compare favorably. They indicate that vegetative characteristics measured early in the season for the "best" and "worst" rows are good indicators of final production under these conditions. The next step would be the expansion of the study into some of the major corn-producing states. This would provide such additional information as cost estimates, consistency of relationships from State to State, and variance components.

The sample fields should probably be selected from the area frame. Furthermore, a random procedure for selecting sample rows and plants should be employed rather than using the "best" and "worst" criteria.

MODEL DEVELOPMENT

The general procedure followed in objective yield surveys is to determine a set of parameters based on historic data. These parameters are then used in a forecasting model to predict future production.

For example, consider the model $Y = a + bx$, where (Y) is final grain weight and (X) is the area of the leaf on node seven obtained during the last week in July. The parameters (a) and (b) can be estimated from previous years data after the final weight is known. Then, given the average area of leaf seven in the following year, the final weight can be predicted using the forecast model.

The success of this procedure depends on one basic assumption. The relationship between (X) and the predicted (Y) is expected to be similar to that in the historic data used to estimate the parameters (a) and (b). The results from the 1968 and 1969 studies showed several variables that were highly correlated with final grain weight. However, for these variables to be effective in a forecasting model, they should show a consistent relationship between the two years.

Simple linear regression coefficients between several of the observed variables and final grain weight were computed for each year. That is, the model $Y = a + bx$ was fitted for each year for each of the variables concerned.

Significance levels were computed for the following tests of hypothesis:

(1) H_0: $Y_i = a_i + bx$ vs. H_a: $Y_i = a_i + b_i x$.

This tests whether the slope between X and Y is the same for each year.

(2) H_0: $Y_i = a + bx$ vs. H_a: $Y_i = a_i + bx$.

Assuming a common slope for all groups, this tests whether the intercepts differ.

Table 13 shows the computed "F" values for each significance test. Under the null hypothesis, a value of 3.96 will be exceeded five percent of the time and 6.96 will be exceeded only one percent of the time. The computed F value in test one for the area of leaf seven in the first week is 13.10. The null hypothesis that the slopes are the same for the two years can be rejected with 99-percent certainty.

A computed "F" greater than 6.96 will occur only one percent of the time if the true "F" distribution follows the null hypothesis. Similarly, a computed value of 3.96 will occur only five percent of the time.

The results for test (1) indicate that the slopes differ significantly between the two years. Similar results occur for test (2). Even though the selected variables are highly correlated with grain weight each year they do not show the same relationship over time. This must be considered when estimating the parameters. Should these differences between years continue to exist in other years and in different States - the use of vegetative characteristics for prediction purposes would be risky.

Table 13.--Computed "F" values for testing differences between regression coefficients for 1968 and 1969, corn, Howard Co., Md.

Variable	Week 1		Week 2		Week 3		Week 4	
	Test Row 1	Test Row 2	Test Row 1	Test Row 2	Test Row 1	Test Row 2	Test Row 1	Test Row 2
Cob length			4.02	9.14	1.06	20.40	1.49	15.28
Leaf area 5	1.58	24.49	1.80	26.90	2.95	24.28	9.18	18.65
Leaf area 7	13.10	17.91	5.63	35.48	.21	35.37	1.52	41.98
Leaf area 11	.00	18.52	1.39	13.94	.11	21.15	.02	22.42
Leaves in whorl	6.37	9.29	----	-----	----	-----	----	-----
Plant height	36.18	15.01	4.40	16.62	1.65	15.24	1.73	18.18
No. nodes	23.82	12.51	1.92	6.07	16.26	12.61	7.13	13.60
No. leaves, basal node to 4th node	1.08	11.79	2.66	4.54	.01	13.07	.38	14.17

MAJOR FINDINGS

(1) Several of the vegetative characteristics observed were significantly correlated with the final yield. These relationships remained consistent over the four-week observation period.

(2) Tests showed that the variables behave similarly over several maturity categories. For example, the area of leaf seven in a simple linear regression with final yield has a common intercept for the different maturity categories. Thus, the data can be pooled and fewer observations would be necessary for a desired precision.

(3) A "stepwise" multiple regression selection procedure showed that additional variables add very little to the precision of the forecasting equation after the area of the seventh leaf is included.

(4) Counts of kernels and ear measurements were highly correlated with dry ear weight. However, several vegetative characteristics performed just as well and can be obtained much earlier in the season.

(5) Simple linear regression between several characteristics and final yield were computed using both 1968 and 1969 data. The regression coefficients were tested to determine if they represented the same relationship each year. They did not. Should this continue to be the case in additional studies, the use of vegetative characteristics may not be warranted.

APPENDIX

<u>Instructions for Corn Research, Howard County, Md., 1969</u>

I. Selecting Sample Rows and Sample Plants

A. Select a "good" row and a "poor" row by subjective evaluation.

(1) Mark the good row with yellow flagging tape and label it Row 1.

(2) Mark the poor row with orange tape. Label it Row 2.

B. Plants 5, 15, 25, 35, and 45 will be tagged with a ribbon (yellow in Row 1, orange in Row 2). Label the ribbons with row and plant numbers.

II. Information Collected and Procedures Followed in the First Week

A. Collect a soil sample two feet to the left of each sample plant. Mark the soil sample box with field, row, and plant numbers.

B. Collect the top two leaves (below the whorl) from the plants opposite to the sample plants in adjacent rows. Place the leaves in a cloth bag and label with field, and row numbers.

C. Install a rain gauge. Pour in a small amount of light oil to prevent evaporation.

III. Observations Obtained Weekly

A. Presence or absence of tassel

B. Height of plant from ground to highest node

C. Number of nodes, excluding basil

D. Measurements at each node:

(1) Length of leaf

(2) Width of leaf at midpoint

(3) Length of cob (if any)

(4) Maturity category of cob, if present

(5) Diameter and circumference of every third internode with random start.

(6) Number of leaves in whorl

E. Rainfall received since previous visit.

IV. Harvest

A. Contact operator to determine probable harvest date.

B. On final visit harvest and label ears from the sample plants.

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1. Remove ear, loose kernels, and pink recording form from bag. Record field, row plants, and ear number on laboratory work sheet.

2. Clean loose silk and husks off the ear.

3. Measure length of the cob:

    i. Place base against box.

    ii. Place ruler next to ear, measure to tip of cob (to nearest 1/16 inch).

4. Measure length of longest kernel row.

    i. Rotate ear to find longest kernel row - then measure to last kernel.

    ii. Define a kernel to be at least three-fourths the size of the average kernel on the cob.

    iii. Determine midpoint of longest row - marked with black magic marker.

5. Measure the circumference of the ear at this midpoint.

6. Count the number of kernel rows, letting row (1) be the row previously marked.

7. Two rows will be selected systematically, and the number of kernels in each row will be counted. An attached sheet will give the rows to be counted for various sizes of n (number of rows).

    i. Count the number of kernels in each row. If there are places where a kernel has been knocked out from handling - count the hole as a kernel.

    ii. The kernels in some rows may not be in a straight line, and may be difficult to count. In this case, place a ruler on the selected row in a straight line from base to tip and count the number of kernels it touches.

8. Weigh ear.

9. Shell using hand sheller.

10. Count the number of kernels.

    i. There may be immature kernels; again do not count unless they are not at least three-fourths the size of the average sized kernel.

    ii. Some kernels may show insect damage; obtain a separate count of these.

11. Weigh kernels.

    i. Whole kernels

    ii. Damaged kernels

    iii. Immature kernels

Row Selection Sheet

If the number of rows is:	Select these rows	
8	1	5
9	4	8
10	5	10
11	1	6
12	6	12
13	4	10
14	2	9
15	1	8
16	4	12
17	8	16
18	9	18
19	3	12
20	6	16
21	9	19
22	2	13

United States Department of Agriculture
Statistical Reporting Service
Research and Development Branch

1969 Laboratory Determinations - Maryland
Vegetative Characteristics Research Project

Field ________ Date ________
Row ________ Starting time ______
Plant ________ Ending time ______
Ear ________

1. Ear length
   a. Length of cob -- ________
   b. Length of longest kernel row ------------------------- ________
2. Midpoint circumference ----------------------------------- ________
3. Number of kernel rows ------------------------------------ ________
4. Number of kernels in selected rows ------------------- a. ________
   b. ________
5. Ear weight --- ________
6. Number of kernels
   a. Whole - mature kernels ------------------------------- ________
   b. Damaged kernels -------------------------------------- ________
   c. Immature kernels (less than three-fourths average size) ________
7. Kernel weight
   a. Whole - mature kernels ------------------------------- ________
   b. Damaged -- ________
   c. Immature --- ________