THE DEVELOPMENT OF OBJECTIVE METHODS

TO FORECAST DRY BEAN YIELD

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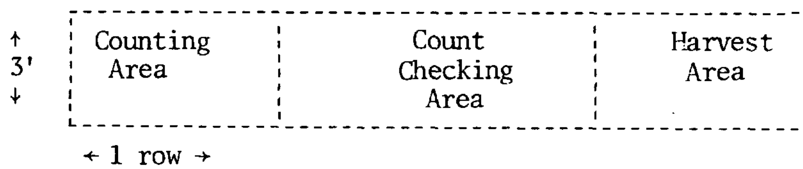
INTRODUCTION

There were two distinct phases to the dry bean objective yield research conducted in Michigan during 1972. The first phase was the plant development study, which was designed to develop models based on pre-harvest plant characteristic counts to forecast weight of beans at harvest and number of mature and dry pods at harvest. The second phase, the plant size study, was designed to determine if any relationship existed between yield and plant size.

DATA COLLECTION

PLANT DEVELOPMENT STUDY:

Eight sample units were non-randomly selected on a commercial bean farm in Gratiot County, Michigan to represent a wide range of field conditions. Within each sample unit four sample sections were located. Each sample section consisted of three areas: (1) counting area, (2) count checking area, and (3) harvest area. Each area was three feet in length and one row in width, and contained a minimum of four plants. The figure below illustrates a sample section. On each weekly visit to the counting and count checking areas, two of the four sample sections in each unit were observed. A fifty percent rotation of sections was used on each visit.



In the counting area, four plants were non-randomly selected by a method that would separate the plants as much as possible to minimize any damage to the plants when performing plant characteristic counts. On each visit to a section, the following plant characteristic counts were recorded on the four selected plants: number of branches, clusters, fresh blossoms, dried blossoms, small green pods, immature pods, and mature and dry pods. When a section in the counting area was considered ready for harvest by the enumerator, pods from the four selected plants were stripped and sent to the laboratory. The following counts were made on the pods collected: pods with beans and without beans, number of beans, number of bad beans, weight of all beans, and weight of bad beans. Bad beans are off-colored, split or defective beans.

In the count checking area, one plant was selected each visit. On the first visit, the second plant closest to the counting area was selected. On the second visit, the fourth plant was selected, et cetera. The same plant characteristic counts were recorded for the count checking area as those recorded for the four plants in the counting area. However, plants in the count checking area were destructively sampled and could be uprooted, if necessary, to provide accurate counts. The purpose of the count checking area was to investigate if vine entanglement and heavy foliage hindered accurate data counting in the counting area.

In the harvest area, four plants in each section were selected at harvest, and pods were stripped and sent to the laboratory. Laboratory counts on these plants were the same as laboratory counts made on plants from the counting area at harvest. The purpose of the harvest area was to determine if any damage had been inflicted to plants in the counting area due to repeated visits by the enumerator.

PLANT SIZE STUDY:

Thirty units six feet in length were selected for the plant size study. Ten units were in Saginaw County on the Michigan State Experimental Farm, and 20 units were located in Gratiot County on a commercial bean farm. Units were selected so that a wide range of plant sizes at maximum growth could be observed. Measurements of plants were made when the plants had transcended full blossom and were considered to have reached maximum growth.

Six one-foot sections were laid out in each unit. Measurements of the height and width were taken in the middle of each one-foot section.

At harvest, plants in one-foot sections were sent to the laboratory, and the following counts were made on pods collected from all the plants in each one-foot section: number of pods, number of beans, number of bad beans, weight of all beans, and weight of bad beans.

DATA ANALYSIS

PLANT DEVELOPMENT STUDY:

(A) Analysis of weekly field observations

(i) By growth code for each plant

One approach to analyzing data collected in the counting area for plant characteristic counts was to classify each plant in each section into a growth code. Thus, forecast models could be produced at different stages of plant growth. The criteria for classifying each plant into a growth code is shown in Table 1. Table 2 gives classification results by date of observation for each plant in the counting area. This table shows that growth code 6 was not observed.

Table 3 gives correlations of plant characteristic counts to number of mature and dry pods at harvest. The null hypothesis being tested is the population correlation coefficient, ρ, is zero. The alternate hypothesis is ρ does not equal zero. Each growth code except growth code 7 had more than one plant characteristic count with a correlation coefficient significantly different from zero at the 99.99% probability level. In other words, for these plant characteristic counts there is 1 chance in 10,000 (1.0000 - .9999 = .0001) of being incorrect in rejecting the null hypothesis. Growth code 7 had one plant characteristic count whose correlation coefficient was significantly different from zero at the 95% probability level (1 chance in 20 of being wrong in rejecting the null hypothesis).

For the dependent variable, mature and dry pods at harvest, the best one-variable linear regression model for each growth code is shown in Table 4. Obviously, a strong relationship exists between the dependent variable and independent variable for each growth code.

Nested or hierarchial classifications occur when a sample is composed of subsamples, which are in turn subsampled. Therefore, nested analysis of variance was performed for each growth code for the independent variable in the linear regression model to determine if a significant difference existed from unit to unit or section to section for the independent variable. The null hypothesis being tested is that no difference occurs for the independent variable at a particular level of sampling. The alternate hypothesis is that a difference exists. Table 5 shows that immature pods were significantly different from section to section at the 95% probability level for growth codes 3 and 4. This means that there is a 5% chance of being wrong in rejecting the null hypothesis. Also, pods were significantly different from section to section for growth code 1 at the same probability level. The remaining independent variables displayed no significant difference for the unit or section level.

Table 1--Criteria for classification into growth code

GROWTH CODE	CRITERIA
	NO MATURE PODS PRESENT
7	BLOSSOMS > PODS Number of blossoms is greater than number of pods
6	BLOSSOMS < = PODS Number of blossoms is less than or equal to number of pods
5	2* BLOSSOMS < = PODS Number of pods is greater than or equal to twice the number of blossoms
4	BLOSSOMS + SMGRPODS < = IMMPODS Number of blossoms plus small green pods is less than or equal to number of immature pods
3	2* (BLOSSOMS + SMGRPODS) < = IMMPODS Number of immature pods is greater than or equal to twice the number of blossoms plus small green pods
	MATURE OR DRY PODS PRESENT
2	BLOSSOMS + SMGRPODS < = MATDRY Number of blossoms plus small green pods is less than or equal to number of mature and dry pods
1	BLOSSOMS + SMGRPODS + IMMPODS < = MATDRY Number of blossoms plus small green pods plus immature pods is less than or equal to number of mature and dry pods
0	SMGRPODS + IMMPODS = 0 All pods are mature or dry

INDEPENDENT VARIABLES:

BRANCHES: number of branches
CLUSTERS: number of clusters
FRESHBLM: number of fresh blossoms
DRIEDBLM: number of dried blossoms
BLOSSOMS: number of blossoms
SMGRPODS: number of small green pods
IMMPODS: number of immature pods
MATPODS: number of mature pods
DRYPODS: number of dry pods
PODS : number of pods
MATDRY : number of mature and dry pods

Table 2--Stage of development by growth code for sample bean plants by date of observation, Michigan 1972.

GROWTH CODE	Number of Plants by Date of Observation: AUGUST 15-21	AUGUST 29 to SEPT. 4	SEPTEMBER 5-11	SEPTEMBER 12-18	SEPTEMBER 19-25	SEPT. 26 to OCT. 2	OCTOBER 3-9	TOTALS
0			3	5	45	75	100	228
1			1		26	1		28
2					1			1
3		15	47	59				121
4		22	5					27
5		22						22
6								0
7	12	1						13
TOTAL	12	60	56	64	72	76	100	440
MATURITY INDEX*	7.0	4.16	2.9	2.76	.38	.013	0	1.595

*MATURITY INDEX for i^{th} week

$$= \sum_{j=0}^{7} \frac{[(\text{number of plants for growth code} = j \text{ in } i^{th} \text{ week})] \quad [\text{Growth Code}]}{TOTAL_i}$$

Table 3--Correlations of plant characteristic counts with number of mature and dry pods at harvest

GROWTH CODE	Plant Characteristic Counts								DEGREES OF FREEDOM
	BRANCHES	CLUSTERS	FRESH BLOSSOMS	DRIED BLOSSOMS	BLOSSOMS	SMALL GREEN PODS	IMMATURE PODS	PODS	
0	.833*	.933*						1.000*	226
1	.875*	.880*					.172	.903*	26
3	.746*	.795*	-.094	.147	.038	.37*	.818*	.736*	119
4	.731*	.771*	.178	.565**	.402***	.747*	.876*	.838*	25
5	.727*	.867*	-.009	.027	.002	.915*	.906*	.934*	20
7	.645***	.422	.495	.281	.49	.046		.046	11

*** Significant at the 95% probability level

** Significant at the 99% probability level

* Significant at the 99.99% probability level

Table 4--Best simple linear regression model by growth code for predicting the dependent variable, mature and dry pods at harvest

GROWTH CODE	EQUATION	R^2
0	Y = PODS*	1.0
1	Y = 1.212 + 0.848 PODS*	.816
3	Y = 4.147 + 0.551 IMMPODS*	.668
4	Y = 1.528 + 0.487 IMMPODS*	.768
5	Y = -1.517 + 0.328 PODS*	.872
7	Y = 1.499 + 0.749 BRANCHES**	.416

* Significant at the 99.99% probability level

** Significant at the 95% probability level

Table 5--Nested analyses of variance

GROWTH CODE	PLANT CHARACTERISTIC COUNT	Source of Variation	Degrees of Freedom	Mean Square	F Value
0	PODS	Unit	7	97.149	.930
		Section	24	104.426	1.171
		Plant	96	89.204	
1	PODS	Unit	7	70.759	.487
		Section	5	145.307	3.998*
		Plant	14	36.345	
3	IMMPODS	Unit	7	27.624	.139
		Section	19	198.708	1.899*
		Plant	63	104.621	
4	IMMPODS	Unit	7	195.811	.545
		Section	7	359.121	4.994*
		Plant	10	71.905	
5	PODS	Unit	6	601.970	.713
		Section	4	844.521	1.181
		Plant	11	715.083	
7	BRANCHES	Unit	1	.235	.035
		Section	2	6.663	.267
		Plant	9	24.972	

*Significant at the 95% probability level.

(ii) By maturity category for each section

Another approach to analyzing data collected in the counting area was to have plants classified into a maturity category by the enumerator in the field. Therefore, forecast models could be produced at different stages of plant growth by maturity category, as was done by growth code. The criteria for classification of plants into a maturity category by the enumerator is given in Table 6.

Maturity categories were determined by section rather than by individual plant. Therefore, the four plants within a section were assigned the same maturity category.

The breakdown for each maturity category by date of observation for all sample plants is shown in Table 7. This table demonstrates that maturity categories 5 and 6 were not observed.

Table 6

MATURITY CATEGORY	CRITERIA
7	Some flowers were open, blooming continues
6	Full blooming, some small green pods
5	Reduced blooming, but leaves still green
4	Some pods are swelling, some yellow leaves
3	Most pods are filled, many yellow leaves
2	Fully developed pods, leaves starting to shed
1	Yellow pods, plants mostly shed
0	Dry pods, plants completely shed

Correlations of plant characteristic counts with number of mature and dry pods at harvest are shown in Table 8. The null hypothesis being tested is $\rho = 0$. The alternative hypothesis is $\rho \neq 0$. For each maturity category except maturity category 7 the correlation coefficient for several plant characteristic counts was significantly different from zero at the 99.99% probability level. In maturity category 7 only one plant characteristic count had a correlation coefficient significantly different from zero at the 95% probability level.

Table 9 gives the best one-variable linear regression model for each maturity category for the dependent variable, mature and dry pods at harvest. Inspection of the linear regression models shows that a strong relationship exists between the dependent variable and independent variable for each maturity category.

Nested analysis of variance was performed for the independent variable in the linear regression model for each maturity category. No significant difference occurred for any independent variable (Table 10) from unit to unit or section to section.

It is easier to have the enumerator visually classify a section than it is to calculate the classification for each plant by the categories listed in Table 1. Therefore, the very similar results obtained for the best one-variable linear regression models by growth code and maturity category are quite encouraging since the models

Table 7--Stage of development by maturity category for sample bean plants by date of observation, Michigan 1972.

MATURITY CATEGORY	Number of Plants by Date of Observation: AUGUST 15-21	AUGUST 29 to SEPT. 4	SEPTEMBER 5-11	SEPTEMBER 12-18	SEPTEMBER 19-25	SEPT. 26 to OCT. 2	OCTOBER 3-9	TOTALS
0					4	24	100	128
1					16	44		60
2				12	48	8		68
3			56	48	4			108
4		60		4				64
5								
6								
7	12							12
TOTAL	12	60	56	64	72	76	100	440
MATURITY* INDEX	7.0	4.0	3.0	2.87	1.63	.79	0	1.95

*MATURITY INDEX for i^{th} week

$$= \frac{\sum_{j=0}^{7} [(\text{number of plants for maturity category} = j \text{ in } i^{th} \text{ week})]\,[\text{Maturity Category}]}{\text{TOTAL}_i}$$

Table 8--Correlations of plant characteristic counts with number of mature and dry pods at harvest

MATURITY CATEGORY	Plant Characteristic Counts								DEGREES OF FREEDOM
	BRANCHES	CLUSTERS	FRESH BLOSSOMS	DRIED BLOSSOMS	BLOSSOMS	SMALL GREEN PODS	IMMATURE PODS	PODS	
0	.852*	.931*						1.000*	126
1	.816*	.931*					.017	.976*	58
2	.833*	.897*					-.031	.918*	66
3	.79*	.83*				.266***	.763*	.786*	106
4	.66*	.77*	-.09	.13	-.079	.616*	.853*	.826*	62
7	.674***	.301	.54	.214	.525	-.06		-.059	10

*** Significant at the 95% probability level

** Significant at the 99% probability level

* Significant at the 99.99% probability level

Table 9--Best simple linear regression model by maturity category for predicting the dependent variable, mature and dry pods at harvest.

MATURITY CATEGORY	EQUATION	R^2
0	Y = PODS*	1.0
1	Y = -0.546 + 0.995 PODS*	.953
2	Y = 1.611 + 0.834 PODS*	.843
3	Y = 2.066 + 0.950 CLUSTERS*	.673
4	Y = 2.472 + 0.500 IMMPODS*	.728
7	Y = 3.863 + 0.671 BRANCHES**	.455

* Significant at the 99.99% probability level

** Significant at the 95% probability level

Table 10--Nested analyses of variance

MATURITY CATEGORY	PLANT CHARACTERISTIC COUNT	Source of Variation	Degrees of Freedom	Mean Square	F Value
0	PODS	Unit	7	27.579	.419
		Section	24	65.826	1.425
		Plant	96	46.195	
1	PODS	Unit	6	57.954	.538
		Section	8	107.672	1.803
		Plant	45	59.728	
2	PODS	Unit	7	87.254	1.773
		Section	9	49.218	1.051
		Plant	52	46.809	
3	CLUSTERS	Unit	7	14.173	.331
		Section	14	42.780	1.050
		Plant	66	40.737	
4	IMMPODS	Unit	7	228.641	.887
		Section	8	257.797	1.802
		Plant	48	143.089	
7	BRANCHES	Unit	1	2.042	.333
		Section	1	6.125	.245
		Plant	9	24.972	

imply forecasting models can be determined by maturity category. For this reason linear regression models for the dependent variable, weight of beans at harvest, were generated only with respect to maturity category.

Table 11 gives correlations of plant characteristic counts with weight of beans at harvest by maturity category. The null and alternate hypotheses are $\rho = 0$ and $\rho \neq 0$, respectively. Again, each maturity category except maturity category 7 had several plant characteristic counts whose correlation coefficient was significantly different from zero at the 99.99% probability level (1 chance in 10,000 of being wrong in rejecting the null hypothesis). Maturity category 7 had one plant characteristic count with a correlation coefficient significantly different from zero at the 99.5% probability level.

In Table 12, the best one-variable linear regression models by maturity category are given for the dependent variable, weight of beans at harvest. The regression coefficient in each model was significantly different from zero beyond the 99% probability level. Table 13 gives 95% confidence intervals by maturity category for ρ and β, respectively.

(iii) Comparison between counting and count checking areas

A paired t^2 test was performed to compare pre-harvest plant characteristic counts in the counting area with pre-harvest plant characteristic counts in the count checking area. The purpose of this test was to determine if vine entanglement and heavy foliage hindered the accuracy of plant characteristic counts in the counting area. Each plant characteristic count mean for the four selected plants in each section of the counting area was compared with the same plant characteristic count on the one plant in the same section for the count checking area.

A two-tailed paired t^2 test for H_o: $\mu_{i,\text{ counting}} = \mu_{i,\text{ count checking}}$; where i = 1, 2,..., p and p is the number of plant characteristics, was not significantly different at the 95% probability level (Table 14). Therefore, for this study there is no evidence that vine entanglement and heavy foliage significantly hinder the accuracy of plant characteristic counts in the counting area.

Table 14--Two-tailed paired t^2 test

Plant Characteristic Counts	Sample Size	t^2 test for H_o	Critical Value t^2 (p, n-1) [α]
Number of:			
Branches Clusters Fresh blossoms Dried blossoms Small green pods Immature pods Mature and dry pods	94	13.440	t^2 (7,93) [.05] = 15.844

Table 11--Correlations of plant characteristic counts with weight of beans at harvest

MATURITY CATEGORY	Plant Characteristic Counts									DEGREES OF FREEDOM
	BRANCHES	CLUSTERS	FRESH BLOSSOMS	DRIED BLOSSOMS	BLOSSOMS	SMALL GREEN PODS	IMMATURE PODS	PODS	MATURE AND DRY PODS	
0	.792*	.864*						.921*	.921*	126
1	.809*	.877*					.070	.901*	.895*	58
2	.831*	.880*					-.094	.880*	.799*	66
3	.735*	.761*				.256***	.687*	.717*	.021	106
4	.655*	.775*	-.020	.207	-.002	.699*	.815*	.850*		62
7	.769**	.510	.403	.213	.397	-.099		-.099		10

*** Significant at the 99% probability level

** Significant at the 99.5% probability level

* Significant at the 99.99% probability level

Table 12--Best simple linear regression model by maturity category for predicting the dependent variable, weight of beans at harvest

MATURITY CATEGORY	EQUATION	R^2
0	Y = .008 + 0.610 MATDRY*	.848
1	Y = -0.462 + 0.628 PODS*	.811
2	Y = .748 + 0.529 PODS*	.775
3	Y = 1.370 + 0.571 CLUSTERS*	.661
4	Y = 1.109 + 0.183 PODS*	.723
7	Y = -3.873 + 0.710 BRANCHES**	.592

* Significant at the 99.99% probability level.

** Significant at the 99.5% probability level.

Table 13--95% confidence interval for ρ by maturity category

MATURITY CATEGORY	Number of Observations	Plant Characteristic Counts	Correlation Coefficient	Confidence Interval for ρ
0	128	MATDRY	.921	.890 < = ρ < = .944
1	60	PODS	.901	.839 < = ρ < = .939
2	68	PODS	.880	.818 < = ρ < = .927
3	108	CLUSTERS	.761	.667 < = ρ < = .831
4	66	PODS	.850	.766 < = ρ < = .906
7	12	BRANCHES	.770	.350 < = ρ < = .932

95% confidence interval for β by maturity category

MATURITY CATEGORY	Number of Observations	Plant Characteristic Counts	Sample Regression Coefficient	Confidence Interval for β
0	128	MATDRY	.610	.565 < = β < = .656
1	60	PODS	.628	.548 < = β < = .707
2	68	PODS	.529	.459 < = β < = .599
3	108	CLUSTERS	.571	.477 < = β < = .664
4	66	PODS	.183	.154 < = β < = .212
7	12	BRANCHES	.710	.295 < = β < = 1.126

(B) Analysis of harvest data:

In the counting area, nested analysis of variance was performed on harvest data to determine if any significant difference occurred from unit to unit or section to section for number of beans at harvest, number of pods with beans at harvest and weight of beans at harvest. Table 15 shows no significant difference was observed from section to section or unit to unit.

A paired t^2 test was performed to determine if any damage had been inflicted to the counting area due to repeated pre-harvest visits by the enumerator. Harvest data from the counting area and harvest area was compared to find out if any significant difference existed. The hypothesis tested was:

$$H_o : \mu_{i,\ counting} = \mu_{i,\ harvest}$$

$$H_A : \mu_{i,\ counting} < \mu_{i,\ harvest}$$

where i = 1, 2, ...,p and p is the number of plant characteristics.

No significant difference was observed for harvest data from the counting and harvest areas. Therefore, for this study there is no evidence that repeated visits by the enumerator inflicted significant damage to the plants (cf. Table 16).

Table 16--Paired t^2 test

Harvest Counts	Sample Size	t^2 test for H_o	Critical Value t^2 (p, n-1) [α]
Number of:			
Pods with beans	127	4.636	t^2 (6,126) [.05] = 13.593
Pods without beans			
Beans			
Bad beans			
Weight of:			
Beans			
Bad beans			

PLANT SIZE STUDY:

An F test was performed to determine if pre-harvest measurements of height and width differed significantly from Gratiot County to Saginaw County. The hypotheses tested were:

$$H_o : \mu_{height,\ Gratiot} = \mu_{height,\ Saginaw}$$

$$H_o : \mu_{width,\ Gratiot} = \mu_{width,\ Saginaw}$$

Table 15--Nested analysis of variance of number of beans at harvest

Source of Variation	Degrees of Freedom	Mean Square	F Value
Unit	7	423.392	.483
Section	24	877.487	1.280
Plant	96	685.299	

Nested analysis of variance of number of pods with beans at harvest

Source of Variation	Degrees of Freedom	Mean Square	F Value
Unit	7	33.924	.434
Section	24	63.510	1.375
Plant	96	46.193	

Nested analysis of variance of weight of beans at harvest

Source of Variation	Degrees of Freedom	Mean Square	F Value
Unit	7	22.935	.747
Section	24	30.690	1.611
Plant	96	19.047	

$$H_A: \mu_{\text{height, Gratiot}} \neq \mu_{\text{height, Saginaw}}$$

and

$$H_A: \mu_{\text{width, Gratiot}} \neq \mu_{\text{width, Saginaw}}$$

The computed F value was large enough to reject the null hypothesis with 1 chance in 10,000 of being incorrect in rejecting H_0. Thus, plant size differed from Gratiot County to Saginaw County.

An F test was also run to determine if harvest data (number of pods, number of beans, weight of good beans, weight of good beans per pod) were significantly different between counties. Good beans are all beans minus bad beans. Based on the computed F value the null hypothesis can be rejected with 1 chance in 200 of being wrong in rejecting H_0. Therefore, harvest data differed significantly from Gratiot County to Saginaw County.

Correlations of height, width and various functions of height and width with yield for Gratiot County and Saginaw County are shown in Table 17 and Table 18, respectively.

The commercial bean farm in Gratiot County demonstrated that plant size and yield were not highly related. A much better relationsip was exhibited between plant characteristic counts and yield in the plant development study.

The experimental farm in Saginaw County displayed an even poorer relationship between plant size and harvest counts.

Based on this study, plant size is a poor predictor of yield.

Table 17--Correlations of pre-harvest plant size for Gratiot County to the following harvest data

Sample Size = 120

PODS WITH BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
.181*	.131	.163	.135	.215*	.041	.048

BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
.177	.117	.153	.125	.225*	.023	.029

WEIGHT OF ALL BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
.131	.041	.097	.049	.260***	-.085	-.074

WEIGHT OF ALL BEANS PER POD WITH BEANS

X1	X2	X3	X4	X5	X6	X7
-.095	-.176	-.126	-.169	.097	-.250**	-.239**

WEIGHT OF GOOD BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
.118	.040	.087	.047	.228*	-.070	-.057

WEIGHT OF GOOD BEANS PER POD WITH BEANS

X1	X2	X3	X4	X5	X6	X7
-.118	-.177	-.144	-.173	.041	-.224*	-.210*

GOOD BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
.160	.109	.137	.116	.197*	.028	.034

*** Significant at the 99.5% probability level
** Significant at the 99% probability level
* Significant at the 95% probability level

VARIABLES:

X1 = 2* Height + Width
X2 = Surface area assuming a parabolic shape for the plant
X3 = Height * Width
X4 = 2* (Height + Width)
X5 = Height
X6 = Width
X7 = Surface area assuming a spherical shape for the plant

Table 18--Correlations of pre-harvest plant size for Saginaw County to the following harvest data

Sample Size = 60

PODS WITH BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
.073	.049	.062	.054	.093	.026	.027

BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
.142	.124	.132	.129	.101	.102	.101

WEIGHT OF ALL BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
-.145	-.136	-.156	-.134	-.092	-.110	-.107

WEIGHT OF ALL BEANS PER POD WITH BEANS

X1	X2	X3	X4	X5	X6	X7
-.306*	-.265*	-.308*	-.268*	-.248	-.200	-.195

WEIGHT OF GOOD BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
-.112	-.057	-.110	-.060	-.216	.006	.011

WEIGHT OF GOOD BEANS PER POD WITH BEANS

X1	X2	X3	X4	X5	X6	X7
-.219	-.134	-.207	-.142	-.341**	-.040	-.033

GOOD BEANS PER PLANT

X1	X2	X3	X4	X5	X6	X7
.136	.155	.133	.157	-.014	.167	.169

** Significant at the 99% probability level
* Significant at the 95% probability level

CONCLUSION

The plant development study has demonstrated that a very strong relationship exists between plant characteristic counts and yield at different stages of plant growth. Linear regression models were adequate for both approaches of classifying plants into a development stage.

For this study repeated pre-harvest visits by the enumerator did not produce any significant damage to plants in the counting area. Also, vine entanglement and heavy foliage did not significantly affect the accuracy of plant counts in the counting area.

The plant size study did not provide as strong a relationship between yield and the independent variables as did the plant development study. Therefore, pre-harvest plant characteristic counts provide a much better method for predicting yield.