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1980 Soybean Destructive Counting Study

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1980 SOYBEAN DESTRUCTIVE COUNTING STUDY. By Roberta B. Pense; Research Division, Statistical Reporting Service. U.S. Department of Agriculture, Washington, D.C. 20250, SRS Staff Report No. AGES810915. September 1981.

ABSTRACT

This report examines the operational practicality of using a destructive counting procedure to obtain plant component counts for the soybean objective yield survey. The study was begun in 1978, and results of the analysis using 1978 and 1979 data are found in ESS Staff Report AGESS801218 entitled, "Soybean Objective Yield Destructive Counting Study" by Dwaine C. Nelson. The present report presents the results using only data collected in Illinois, with special emphasis on 1980 data. The plant component counts obtained from the two methods (destructive and the current nondestructive methods) and the forecasting abilities of the two methods are compared. Methods of modifying the destructive count forecasting models with the hope of improving them are also examined.

ACKNOWLEDGEMENTS

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INTRODUCTION

The Soybean Objective Yield Destructive Counting Study was conducted in Illinois in 1978, 1979 and 1980, Arkansas in 1979, and Ohio in 1979 by the Yield Research Branch of the Statistical Reporting Service (SRS). The purpose of this study was to investigate the desirability of using a different method of collecting soybean objective yield data. An analysis of the data collected in Illinois, with special emphasis on the 1980 data, is presented in this paper. Analysis of the Arkansas and Ohio data, and a year-by-year analysis of the Illinois 1978 and 1979 data were presented in ESS Staff Report No. AGESS801218 entitled, "Soybean Objective Yield Destructive Counting Study" by Dwaine C. Nelson.

The objective yield forecast of gross yield per acre is determined by multiplying three values -- forecasted number of plants, forecasted number of pods per plant, and an historical average weight of beans per pod. The number of plants is forecast by either a curvilinear or linear regression equation, using the plant count obtained in the 3½ foot by 2 row plot as the independent variable. The weight per pod is an historical average based on the weight of pods at maturity in the three foot by one row area. The number of pods per plant is forecast by a multiple regression equation which uses detailed counts obtained from a six-inch by two row plot as the independent variables. Nine plant components, such as number of lateral branches, etc., are counted by the enumerator while the plants are standing in the field. The same plants are observed monthly from two/three months prior to maturity through the mature stage. Concern has arisen over the data collection difficulties caused by heavy vegetation and unfavorable field and weather conditions. These conditions could cause enumerator fatigue and counting errors. A destructive counting procedure was, therefore, developed in order to reduce these data collection difficulties. The plants in the six-inch by two row detailed plot are removed from the field prior to making the detailed counts. A different set of plants are, therefore, observed each month. This method should also reduce any nonsampling errors due to the repeated handling of the same plants each month or the destruction of surrounding competition. However, since different plants are observed each month, the variability of the plants within the field will affect the useability of the destructive counts in constructing forecast equations. The 1971 paper "Using Objective Measurements of Plant and Soil Characteristics to Forecast Weight of Grain Per Head for Winter Wheat", by William H. Wigton and Fred B. Warren outlined the potential effect of using destructive plots in building linear regression models. The authors pointed out that the regression coefficients are biased downward, which increases the forecast errors for non-average observations of the independent variable. The amount of bias is dependent on the variability of the independent variable within the field. Ronald Wood takes up the discussion in his 1972 paper, "Grain Sorghum: A Preliminary Forecast Model". He illustrates the effect of using destructive plots, thereby introducing measurement errors, when multicollinearity exists in a multiple regression model.

The objective of the three-year study was to examine the operational practicality of the destructive counting procedure with respect to the current nondestructive approach. Specifically, this involved:

1. Evaluating of the efficiency and quality control procedures using the destructive method. In the earlier paper, Nelson concluded that the destructive procedure is operationally efficient and that quality control procedures are available. Since no additional data concerning these subjects were collected in 1980, no additional analysis is presented in this paper.

2. Comparison of the counts obtained using the destructive procedure with the counts obtained using the objective yield nondestructive procedure. The comparisons were originally done in order to evaluate whether or not the destructive counts could be used in the current objective yield models. If no significant difference in counts existed, the need for a three-year accumulation of data for building the pods per plant forecasting model would be eliminated. Because significant differences in counts were found in Illinois in 1978 and 1979, additional data were collected in an attempt to identify the reasons for nonsampling errors (i.e., counting errors or handling effect) in 1980.

3. Evaluation of the forecasting models using the destructive counting data. Because the weight per pod is an historical average, based on the three foot data, and the effect of the six-inch number of plants on the forecast number of plants is minimal, this study concentrates on the forecast models for pods per plant. In the earlier paper, Nelson concluded that the destructive method does not appear to forecast at a level acceptable to the standards of SRS. However, because the destructive procedure was so desirable from a data collection standpoint, the study was continued for another year. The present paper analyzes the 1980 data and also examines methods of modifying the destructive models with the hope of improving them.

DATA COLLECTION

The two regular objective yield units (that is, the two 3-foot by 2-row and 6-inch by 2-row plots) were located as usual and the counts were made nondestructively. In Illinois, even-numbered samples are first visited in August, whereas the odd-numbered samples are visited for the first time in September. At each monthly visit to the objective yield units, one six-inch by two-row (the same size as the detailed count unit) destructive count unit was laid out near the objective yield plot. The location of the destructive plot with respect to the objective yield plot was randomly selected each month. See Figure 1. Plants from the destructive plot were removed from the field in plastic bags. Counts were completed at the field entrance or some other convenient location. The same plant components were counted on both the destructive and nondestructive plants. Refer to the enumerator's manual for the objective yield survey and the 1978, 1979 and 1980 research studies for further information.

In 1980, an additional six-inch by two-row plot was located 5½ feet beyond the three foot objective yield plot of unit one on the final preharvest visit. The number of pods on each plant was nondestructively counted and recorded

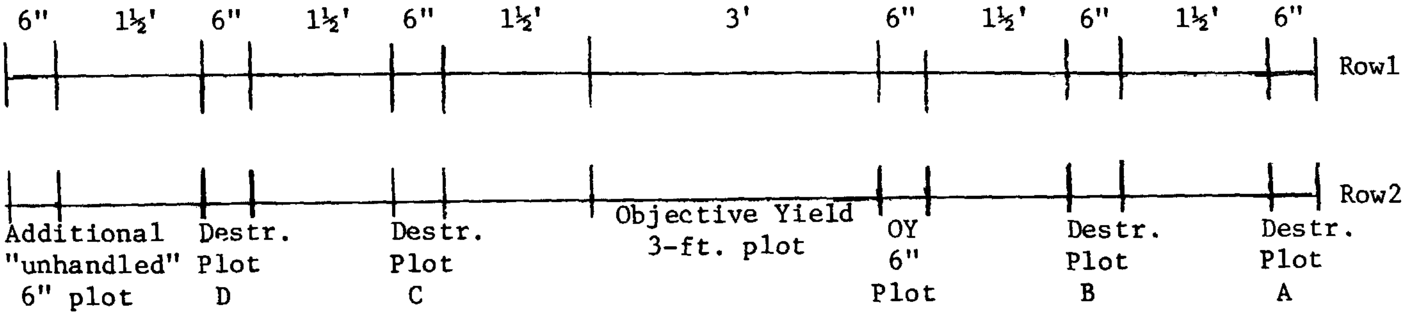

Figure 1: Destructive Plot Positions in Relation to an Objective Yield Unit

on a plant-by-plant basis. The "unhandled" plot was, therefore, counted in the same manner as the objective yield plot. It was hoped that these data would help identify the reasons for the difference between the counts of pods per plant at harvest in Illinois in 1978 and 1979 using the two counting methods.

COMPARISON OF COUNTS

A multiple paired t-test, also known as the Bonferroni method, was used to examine the data for consistent differences between counts obtained using the objective yield procedure and the counts using the destructive counting procedure. As stated in the earlier report, the multiple paired t-test was used because the interest was in making comparisons involving the mean of each variable. This test takes into account the fact that several tests are made concurrently, and that high correlations among variables affect the probability of obtaining additional significant results once one of the comparisons is found to be significant. In addition, this test procedure results in a more powerful test of the mean differences because the data are paired.

The null hypothesis is H_o: $\bar{D} = 0$ versus H_a: $\bar{D} \neq 0$. The test statistic is:

$$t = (\bar{D} - U_D) / S_{\bar{D}} \text{ where } \bar{D} = \Sigma_i D_i / n$$

where $U_D = 0$ under the null hypothesis

D_i = difference between the destructive and objective yield counts for the i^{th} plot,

$$S_{\bar{D}} = \sqrt{\frac{\sum_{i=1}^{n} (D_i - \bar{D})^2}{n - 1}} \Big/ \sqrt{n}$$

n = number of paired plots,

t is distributed $t\ (1 - \alpha/2k,\ n-1)$,

k = number of comparisons being performed each month.

If $\left|\frac{\bar{D}}{S_{\bar{D}}}\right| > t(1 - \alpha/2k,\ n-1)$ then the null hypothesis that the difference in counts for that variable is equal to zero is rejected. The multivariate hypothesis that the two counting procedures produce the same counts over all variables is rejected with a significance level less than or equal to α if at least one of the k individual comparisons is rejected. The text, Multivariate Analysis with Applications in Education and Psychology, by Neil H. Timm (Brooks/Cole Publishing Co., 1975) contains more information on this test.

The comparison of per plant counts for Illinois in 1980 is shown in Table 1. Contrary to the results obtained in previous years, there were no significant differences in the counts obtained by the two methods in any of the months or at maturity. In 1978 and 1979, the destructive counts, particularly the pod counts at maturity, were higher than the nondestructive counts when the crop reached maturity. An analysis of variance test on the difference between pods per plant at maturity obtained from the two counting methods shows a significant year effect (α = .02). The average difference (objective yield - destructive) in pods per plant at maturity was -0.35 in 1980, -4.64 in 1979, and -5.65 in 1978. Using a Duncan's Multiple Range Test, there is a significant difference between the 1980 results and the 1978 and 1979 results. The average nondestructive count of pods per plant was 32.23 in 1980, 32.06 in 1979 and 31.85 in 1978. There was no significant year effect. The average destructive count of pods per plant was 33.00 in 1980, 36.22 in 1979 and 37.93 in 1978. There was almost a significant year effect (α = .055).

Since the objective yield count of pods per plant remained relatively constant over all three years, while the destructive yield count dropped approximately four pods per plant in 1980, it appears that either the enumerators were better able to nondestructively count the pods with beans per plant in 1980 than in 1978 and 1979 or the handling effects on the objective yield plants were different in 1980 as opposed to 1978 and 1979. Several hypotheses to explain the year effect have been proposed.

The hot and dry 1980 season may have caused the soybean plants to produce fewer, but more filled pods, and less vegetation. The enumerators could then more easily identify pods with beans (as opposed to pods without beans). Looking at the weight per pod (unadjusted for moisture content) for the three years, there was no significant year effect (α = .05). The average unadjusted weight per pod was .56 in 1978, .55 in 1979 and .53 in 1980. Thus, the pods do not appear more filled in 1980. In addition, heavy vegetation should not be a major factor in counting errors at maturity, since at least half of the leaves have shed. There are no counts taken at maturity that can be used to test vegetation effects.

Table 1: Paired Comparison of Destructive and Objective Yield Counts, Illinois 1980

Variable	AUGUST 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=160	SEPTEMBER 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=312
Mainstem nodes per plant	14.94	14.78	.17	.82	17.38	17.12	.26	1.22
Lateral branches per plant	1.27	1.33	- .06	- .65	1.62	1.66	- .04	- .52
Lateral branch nodes w/fruit per plant 1/	4.78	5.12	- .33	- .82	6.59	6.62	- .03	- .09
Fruit on lateral branches per plant 1/	12.48	13.21	- .72	- .70	12.93	13.00	- .07	- .07
Mainstem nodes with fruit per plant 1/	9.15	9.08	.07	.35	12.27	12.09	.18	.88
Fruit on mainstem per plant 1/	36.27	35.63	.59	.50	37.23	37.43	- .20	- .23
Blooms per plant	10.94	12.36	-1.42	-2.26	.18	.16	.02	.61
Nodes with fruit buds only per plant	1.60	1.66	- .06	- .53	.12	.12	- .00	- .33
Pods with beans per plant	3.75	2.73	1.01	2.76	35.77	34.71	1.06	.92
Plants	6.03	6.04	- .01	- .04	5.91	6.04	- .12	- .65

Variable	OCTOBER 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=310	NOVEMBER 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=67
Lateral branches per plant	1.37	1.51	- .14	-1.95	1.46	1.44	.02	.15
Lateral branch nodes with pods per plant	4.97	5.21	- .24	- .69	5.49	4.20	1.29	1.36
Pods on lateral branches per plant	8.07	7.79	.28	.32	8.71	6.09	2.62	1.60
Mainstem nodes with pods per plant	10.97	10.56	.41	2.11	10.55	9.90	.65	2.00
Pods on mainstem per plant	26.07	25.40	.67	.99	25.66	22.98	2.68	2.38
Pods with beans per plant	32.15	31.28	.87	.73	31.99	27.36	4.63	1.93
Plants	5.96	5.89	.07	.33	5.40	5.85	- .45	-1.25

Variable	ALL MATURE SAMPLES 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=332
Lateral branches per plant	1.42	1.55	- .12	-1.68
Lateral branch nodes with pods per plant	5.19	5.32	- .13	- .35
Pods on lateral branches per plant	8.49	7.98	.51	.54
Mainstem nodes with pods per plant	10.95	10.53	.42	2.18
Pods on mainstem per plant	26.32	25.49	.83	1.21
Pods with beans per plant	32.78	31.65	1.13	.89
Plants	5.93	5.83	.10	.51

1/ Fruit defined as bloom, dried flowers, and pods.
2/ No significant differences in paired means at the overall multiple-t significance level of α = .05.

Another hypothesis is that pods with beans identification using the nondestructive method may have been influenced by the additional experience in the destructive counting procedure. Under the current objective yield procedure, enumerators are instructed to open pods of similar size outside the unit to determine whether or not the pods contain beans whenever they are in question. However, enumerators may not be doing this. The destructive counting procedure allows the enumerator to open the pod in question. Thus, it is possible that enumerators discovered that questionable pods, which they had classified as not having beans in previous years, did in fact contain beans. Several enumerators were contacted and asked if they felt that the destructive method influenced the 1980 nondestructive counts. These enumerators did not feel that their objective yield counts were affected in any way by the nondestructive counts. While the enumerator-experienced hypothesis does not appear to have strong support, it cannot be declared disproven since the sample was not drawn statistically. Moreover, the destructive method may have had a subtle effect on the objective yield counts, an effect which was not noticed by the enumerators.

Sufficient data were not available to test a change in handling effects over the years. Data on pods with beans per plant were collected in 1980 at the final preharvest visit using the nondestructive counting method on an additional "unhandled" six-inch plot for each sample. Since a difference in pods per plant for the two counting methods found in 1978 and 1979, these data were to be used to test whether the difference was due to the repeated handling of the objective yield plots or due to reduced counting errors using the destructive method. There was no significant difference ($\alpha = .05$) between the counts obtained from the three plots, i.e., the objective yield six-inch plot, the destructive six-inch plot and the additional "unhandled" six-inch plot. Thus, there does not appear to be either a handling effect or a counting effect in the 1980 data.

FORECASTING ABILITY

One of the major objectives of the Soybean Objective Yield Survey is to provide early-season forecasts of soybean yield. The forecasts are based upon the relationship between early-season plant counts and end-of-season yield. According to Methods Staff, the current objective yield program uses a forward selection stepwise procedure to derive the "best" regression models for number of pods with beans per plant by maturity category, using data from the previous three years. Both the enumerator's observed maturity stage and the relationship between plant components are used to stratify the data into maturity categories. Maturity categories and stages are defined in Appendix I.

The independent variables considered for models to forecast number of pods with beans per plant are listed in Appendix II. These independent variables are from the 6-inch section, with the exception of the variable, plants per 18-square feet (which includes the plant count from both the 6-inch and 3-foot sections). The current objective yield program uses the number of pods with beans per plant at maturity in the 6-inch section as the dependent variable. Since the same plants are counted throughout the season, relatively strong relationships can be developed for forecasting purposes. However, if the number of pods with beans has been reduced due to plant handling, both the early-season forecasts, which use historic models, and the end-of-season estimates will tend to be biased downward. With the destructive procedure no opportunity exists to use a dependent variable from the same plants counted early in the season. An alternative source of the dependent variable, number of pods with beans per plant, is the 3-foot section.

The forecasting abilities of the two counting methods were compared. Four sets of "best" regression models were derived by using a forward selection technique. Inferences are only made for other samples which are drawn in the same manner as these were. Therefore, there is no need to adjust because of the sampling scheme. The models are as follows:

Model 1: Destructive early-season counts per plant regressed on the final count of pods with beans per plant from the 3-foot section. This is the destructive model.

Model 2: Objective yield early-season counts per plant regressed on final count of pods with beans per plant from the 3-foot section. This model is presented because it illustrates the effect of not using the same plants for both the dependent and independent variables.

Model 3: Destructive early-season counts per plant regressed on the final count of pods with beans per plant from the objective yield 6-inch plot. This model is presented because in trying to improve the destructive model, it was necessary to assume the objective yield 6-inch plot provided the dependent variable.

Model 4: Objective yield early-season counts per plant regressed on the final count of pods with beans per plant from the objective yield 6-inch plot. This is the current objective yield nondestructive model.

Table 2 shows the R^2 values and the number of observations from the four models by month and maturity category for Illinois in 1980. Table 3 shows the same information when the 1978, 1979 and 1980 Illinois data are combined. As was noticed in the previous report, the destructive models are as good as the objective yield (nondestructive models) for the lower maturity categories. However, the R^2 for the destructive models are lower than the objective yield model R^2 for the higher maturity categories. The forecasting models using 1980 data only are found in Table 1 of Appendix III. The models derived from the combined 1978-80 data are shown in Table 2 of Appendix III.

In order to examine the relative importance of the variables in each of the models, the regression coefficients were standardized. Table 4 shows the relative importance of the variables by month and maturity category for Models 1 and 4. As can be seen, the objective yield model (Model 4) considers the pods with beans per plant to be the most important variable

Table 2: Illinois R^2 Values Obtained from Forecasting Models, 1980

Monthly Maturity Category	Model 1 n	Model 1 R^2	Model 2 n	Model 2 R^2	Model 3 n	Model 3 R^2	Model 4 n	Model 4 R^2
Aug								
1	8	.767	10	.775	8	.294	10	.361
2	17	.743	20	.494	—	---	20	.670
3	33	.398	34	.351	33	.246	34	.560
4	36	.890	31	.758	36	.629	31	.635
5	42	.408	48	.602	41	.243	48	.757
Sept								
7	30	.770	48	.826	28	.403	48	.943
8	149	.444	150	.474	151	.245	151	.881
9	119	.489	107	.455	116	.388	108	.834
Oct								
9	13	.604	12	.475	12	.751	12	.999
10	36	.578	39	.411	37	.584	40	.884

Table 3: Illinois R^2 Values Obtained from Forecasting Models, 1978, 1979 and 1980 Combined

Monthly Maturity Category	Model 1 n	Model 1 R^2	Model 2 n	Model 2 R^2	Model 3 n	Model 3 R^2	Model 4 n	Model 4 R^2
Aug								
1	34	.638	40	.525	34	.296	32	.390
2	36	.595	61	.426	34	.069	46	.567
3	52	.390	89	.353	50	.290	72	.432
4	104	.579	92	.527	102	.423	82	.515
5	63	.435	69	.528	61	.239	64	.653
Sept								
6	11	.669	12	.771	10	.904	11	.845
7	76	.607	103	.541	62	.323	83	.877
8	380	.464	383	.455	326	.232	328	.832
9	248	.493	221	.394	198	.360	183	.857
Oct								
9	58	.528	60	.564	45	.485	46	.970
10	107	.288	109	.192	87	.380	90	.881

Model 1: Independent variables from destructive 6-inch plot, dependent variable from 3-foot section.

Model 2: Independent variables from objective yield 6-inch plot, dependent variable from 3-foot section.

Model 3: Independent variables from destructive 6-inch plot, dependent variable from objective yield 6-inch plot.

Model 4: Independent and dependent variables from objective yield 6-inch plot.

Table 4: Relative Importance of Independent Variables in Regression Equations, Illinois 1978-80
Combined by Month and Maturity Category*

Var	MATURITY CATEGORIES																									
	AUGUST												SEPTEMBER						OCTOBER			
	1		2		3		4		5		6		7		8		9		9		10	
	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4	Mod 1	Mod 4
X4	---	1.49	---	1.30	---	1.17	4.86	2.49	4.85	---	---	---	5.86	---	181.28	---	4.24	19.49	---	3.08	3.44	1.00
X8	21.30	---	1.00	1.57	5.89	---	14.31	15.39	---	1.75	24.75	2.26	7.42	---	8.31	2.92	5.89	---	1.28	---	6.71	1.77
X9	11.43	1.59	---	---	1.29	---	1.24	---	1.00	---	12.01	---	1.00	4.24	---	5.72	1.76	6.79	1.00	---	9.07	---
X10	(46.87)	(2.73)	---	1.00	2.53	---	---	2.87	(5.75)	(3.24)	---	---	6.55	1.00	(182.02)	---	---	---	---	---	---	---
X12	---	---	---	---	1.00	---	---	---	---	1.00	13.30	(2.54)	4.05	(8.14)	7.57	(17.15)	7.20	(48.65)	1.49	(16.59)	(13.82)	(8.07)
X13	33.19	---	---	1.00	1.40	1.00	1.60	1.00	---	---	1.00	---	---	1.73	1.00	2.78	1.00	4.54	---	1.22	1.00	---
X14	14.46	1.00	---	---	---	(3.27)	---	3.54	1.49	1.16	---	---	1.32	1.75	1.53	1.00	---	---	---	1.00	---	---
X15	32.02	2.44	(1.29)	---	(9.65)	1.16	(20.46)	(20.64)	3.33	2.34	(26.90)	---	(7.96)	---	13.29	4.34	(9.29)	1.00	(1.60)	---	9.51	1.41
X16	1.00	---	---	(4.01)	---	1.03	1.00	5.18	3.31	---	---	1.00	---	5.48	4.02	4.26	---	---	---	2.94	---	1.74

* The variable which is least important in the regression equation is given a value of 1.00. The other variables are assigned values relative to the least important variable. The most important variable is in parentheses. The values for variable X12 are underlined since this variable is pods with beans per plant.

beginning with maturity category 6. The destructive model (Model 1) does not consider this variable to be the most important until maturity category 10. The number of plants (X15) appears as the most important variable for the destructive model in most maturity categories. Since the number of plants stabilizes early in the season, the destructive models do not appear to be sensitive to late-season changes.

The forecasting abilities of the two models were also compared by looking at the 1980 forecasted pods with beans per plant. The forecasts were based on the regression equations developed from the 1978 and 1979 data, and the actual count of pods with beans at maturity from the 3-foot section. Two variables, the difference between forecast and actual pods with beans per plant, and the absolute value of the difference in forecast and actual pods, are compared using unpaired t-tests. A summary of the results is found in Table 5. As can be seen there are significant differences in the errors in forecasting for the two methods for maturity categories 1, 2, 3, 6 and 10. There are significant differences in the absolute values of the errors for maturity categories 1, 6 and 9. Further examination of the data shows that the destructive model forecasts for maturity category 6 produced the largest errors. This might be expected since there were only ten observations used to develop the destructive model at this maturity category. It is somewhat surprising, however, that significant differences due to counting methods exist mainly in the lower maturity categories rather than the higher ones. The objective yield models were considered more responsive to late season changes than the destructive models, therefore, differences in the forecasting abilities of the models would be expected to be greater in the higher maturity categories. A possible explanation is that there were no late season changes in 1980, since most stress in 1980 occurred early in the season. The destructive models were, therefore, able to reflect this stress.

Attempts have been made to improve the destructive models. The 1978-79 analysis examined the possibility of sampling more plants. Data from the destructive six-inch plot were combined with the data from the objective yield six-inch plot. The 3-foot pods with beans per plant were then regressed on the combined one-foot counts. This analysis did not appear very promising in 1978-79, and it was not repeated in 1980. A nested analysis of variance was performed on the pods per plant data obtained from the additional "unhandled" plot at maturity to get a better idea of the plant variability within a sample plot. The analysis of variance table is shown below:

Source	df	MS	E(MS)	Estimated Variance Component
sample	143	1545.36	$5.44\ \sigma_s^2 + 3.18\ \sigma_r^2 + \sigma_p^2$	104.15
row	122	883.32	$2.68\ \sigma_r^2 + \sigma_p^2$	188.78
plant	519	378.32	σ_p^2	378.32

Table 5: Comparison of the Objective Yield and Destructive Count Models with Respect to 1980 Forecasting Errors Based on 1978-79 Regression Equations

Month	Maturity Category	Count Method	No. of Observations	Average forecast-actual	Average |forecast-actual|
Aug	1	obj. yld.	10	-12.41	12.41
		destructive	8	-27.20**	27.20**
	2	obj. yld.	20	16.34	16.34
		destructive	17	- 5.90**	13.45
	3	obj. yld.	34	-19.53	20.14
		destructive	33	- 5.75*	19.50
	4	obj. yld.	31	4.24	10.19
		destructive	36	1.92	10.00
	5	obj. yld.	48	11.06	13.71
		destructive	42	6.42	15.20
	6	obj. yld.	5	- 4.14	7.15
		destructive	11	82.23**	82.23**
	1-6	obj. yld.	154	.84	14.26
		destructive	155	4.77	20.12**
Sept	7	obj. yld.	48	- 3.28	10.02
		destructive	30	- 3.10	10.87
	8	obj. yld.	150	3.34	11.63
		destructive	149	1.13	9.87
	9	obj. yld.	107	- 0.31	12.41
		destructive	119	2.12	9.20*
	7-9	obj. yld.	314	0.94	11.64
		destructive	306	1.43	10.01
Oct	9	obj. yld.	12	0.32	8.49
		destructive	13	4.58	8.78
	10	obj. yld.	39	- 5.19	10.80
		destructive	36	2.20*	7.83
	9-10	obj. yld.	51	- 3.90	10.26
		destructive	49	2.83*	8.08
All	1-10	obj. yld.	519	0.44	12.28
		destructive	510	2.58	12.90

* indicates the two models produce significantly different forecast errors (α = .05).
** indicates the two models produce significantly different forecast errors (α = .01).

The sample effect is significant at the α = .05 level (F=1.58 with 143 and 105 degrees of freedom using Satterwaithe's approximation) and the row effect is highly significant (α = .01, F=2.33 with 122 and 519 degrees of freedom). It was also found that the number of pods with beans on first plant in the plot was highly correlated (α = .01) with the number of the second plant (r = .36), and correlated (α = .05) with the number on the third plant (r - .19). The number of pods on the first plant was not significantly correlated with the pod counts of any other plants in the plot. Thus, it appears that there is a great deal of variability within the field even among nearby plants.

Another method of improving the destructive models involves a double sampling approach. Some variables, such as number of plants, number of laterals, and number of main stem nodes with pods can be counted in the plot from which the dependent variable is taken. More detailed counts can be made in the destructive 6-inch plot. This information can then be used in various ways. One method uses the detailed destructive counts as functions of number of plants, lateral branches and main stem nodes (i.e., the counts made in the dependent variable's plot). See Table 3 in Appendix III. These equations could then be used to calculate adjusted per plant counts. The adjusted counts are estimates of the counts which would have been obtained from the dependent variable's plot if they had been made. Regression models using the number of plants, laterals per plant, and main stem nodes per plant from the dependent variable's plot and the adjusted counts could then be developed to forecast pods with beans per plant. This is referred to as Model 5. A second regression approach continues to use the destructive per plant counts as the independent variables, but includes additional independent variables. These variables would be the differences in number of plants per unit area, lateral branches per plant, and main stem nodes per plant, between the dependent variables plot and the destructive six-inch plot. This model is referred to as Model 6. In practice, the dependent variable would be taken from the 3-foot section. However, since no additional counts were made in the 3-foot section, this analysis assumes the dependent variable was taken from the objective yield 6-inch plot. The number of observations and R^2 values by month and maturity category for these two models are found in Table 6. The adjusted destructed models show considerable improvement over the unadjusted destructive model (Model 1). However, they do not appear to be as good as the nondestructive model (Model 4). Table 4 in Appendix III presents the regression equations by month and maturity category for the two adjusted models. The relative importance of each variable is shown in Table 7. Model 6 considers the difference in main stem nodes per plant between the two plots to be the most important variable beginning with maturity category 6. Number of pods with beans per plant remains less important. While X12, number of pods with beans per plant, is not usually considered the most important variable in Model 5, this variable or its squared value, X9, is considered the second most important variable beginning with maturity category 6.

The advantages of the destructive counting procedure must be weighed against the disadvantages of not observing the same plants throughout the season. The use of the unadjusted destructive counting procedure is clearly unacceptable because the models do not reflect late-season changes adequately, even

Table 6: Illinois R^2 Values Obtained from Adjusted Regression Models

Monthly Maturity Category	1980 Model 5 n	1980 Model 5 R^2	1980 Model 6 n	1980 Model 6 R^2	1978 - 1980 Model 5 n	1978 - 1980 Model 5 R^2	1978 - 1980 Model 6 n	1978 - 1980 Model 6 R^2
Aug								
1	7	1/ 1.000	7	1/ 1.000	33	.603	33	.759
2	16	.698	16	.886	34	.522	34	.692
3	33	.462	33	.421	50	.428	50	.472
4	36	.514	36	.771	102	.484	102	.600
5	41	.581	41	.711	61	.543	61	.615
6	11	.908	11	1/ 1.000	16	.595	16	.996
Sept								
7	28	.800	28	.807	62	.632	62	.690
8	151	.690	151	.710	325	.708	326	.723
9	116	.674	115	.707	198	.706	198	.739
Oct								
9	12	.834	12	.947	45	.790	45	.921
10	37	.735	37	.839	87	.506	87	.675

Model 5: Dependent variable from the objective yield 6-inch plot. X8, X15, X13 and X14 are from the objective yield 6-inch plot. X12A, X9A, X4A, X10A, X16A are estimated variables. These variables are based on regression equations developed from the destructive 6-inch plot, and are functions of X8, X15, X13 and X14.

Model 6: Dependent variable from the objective yield 6-inch plot. Independent variables from the destructive 6-inch plot. Four additional independent variables are included which are the difference between the objective yield and destructive 6-inch plot counts for X8, X15, X13, and X14 and the squared difference for X15.

1/ Number of independent variables equaled or exceeded number of observations.

Table 7: Relative Importance of Independent Variables in Adjusted Regression Equations, Illinois 1978-80 Combined by Month and Maturity Category*

Var	MATURITY CATEGORIES																					
	AUGUST												SEPTEMBER						OCTOBER			
	1		2		3		4		5		6		7		8		9		9		10	
	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6	Mod 5	Mod 6
X4	1.00	---	---	1.32	---	---	---	---	(14.72)	1.80	1.00	44.58	(52.98)	---	---	---	---	---	1.00	3.44	7.00	(30.89)
X8	---	---	---	---	---	8.92	---	5.13	---	1.00	---	65.60	---	6.46	1.00	4.67	---	1.18	---	5.54	---	---
X9	58.51	1.95	4.19	---	---	1.00	---	---	3.52	---	---	20.61	---	5.45	4.95	---	1.00	---	(1.36)	3.45	6.85	6.59
X10	---	4.41	---	---	(2.88)	2.36	---	3.36	---	---	---	48.72	---	---	---	2.29	(3.75)	2.87	---	---	---	---
X12	---	---	1.00	---	1.30	---	---	---	---	---	(1.47)	1.57	52.13	2.94	---	5.82	3.38	4.04	---	1.21	(16.28)	21.21
X13	---	2.08	---	---	---	---	---	2.82	---	4.81	---	9.22	1.00	12.93	(5.47)	22.43	1.36	3.07	1.24	5.45	1.00	14.87
X14	(159.16)	---	(6.53)	(4.66)	1.88	5.81	---	1.00	---	6.06	---	6.12	---	---	---	7.22	---	2.02	---	---	---	5.21
X15	2.21	1.74	---	---	1.00	(14.22)	1.00	(8.81)	1.00	---	---	(71.11)	5.56	1.00	2.04	9.30	---	1.90	---	6.58	---	4.80
X16	152.35	---	---	2.89	---	---	(1.88)	1.56	---	---	---	17.56	---	2.31	---	2.78	---	1.00	---	---	---	1.00
DIFFPL	---	3.09	---	3.46	---	3.25	---	1.78	---	1.43	---	1.92	---	3.42	---	1.00	---	---	---	1.03	---	1.24
DIFFPL2	---	1.00	---	1.00	---	1.96	---	---	---	---	---	1.00	---	1.07	---	1.03	---	---	---	1.00	---	8.33
DIFFNOD	---	1.30	---	1.74	---	4.06	---	3.18	---	(8.57)	---	6.43	---	(14.68)	---	(25.26)	---	(4.12)	---	(6.84)	---	17.60
DIFFLAT	---	(8.07)	---	3.61	---	7.01	---	2.88	---	2.70	---	1.61	---	5.06	---	14.00	---	1.94	---	2.44	---	7.82

* The variable which is least important in the regression equation is given a value of 1.00. The other variables are assigned values relative to the least important variable. The most important variable is in parentheses. The values for variable X12 is underlined since this variable is pods with beans per plant.

Model 5: Dependent variable from objective yield 6-inch plot. X8, X15, X13 and X14 are from the objective yield 6-inch plot. X12, X9, X4, X10 and X16 are estimates of the per plant counts which would have been obtained from the objective yield plot if they had been made.

Model 6: Dependent variables from the objective yield 6-inch plot. The X variables are from the destructive 6-inch plot. DIFFPL, DIFFPL2, DIFFNOD and DIFFLAT are the difference (6-inch objective yield -- 6-inch destructive plot) for X15, X8, X13 and X14.

though they forecasted the 1980 pods per plant as well as the objective yield models. Model 6 also does not adequately account for late-season changes. Model 5 performs more satisfactorily, but not as well as the nondestructive model. Some of the advantages of the destructive counting procedure are lost, however. While the adjusted destructive counting procedure will ease the enumerators workload, some additional counts would have to be made in the 3-foot section; thus, increasing time in the field. In addition, some handling effect may be introduced into the 3-foot section. Other methods of adjusting data, which require less detailed count data from the three-foot unit, were examined. The R^2 and the explanations of these models are shown in Table 8. The relative importance of variables in Models 8 and 9 are shown in Table 9. These models do not appear to be as good as Model 5, and are clearly not as good as Model 4 (nondestructive model).

Table 8: Illinois R^2 Values Obtained from Adjusted Destructive Forecasting Models, 1978, 1979 and 1980 Combined

Monthly Maturity Category	Model 7		Model 8		Model 9	
	n	R^2	n	R^2	n	R^2
Aug						
1	33	.267	33	.296	33	.562
2	34	.050	34	.088	34	.541
3	50	.329	50	.341	50	.447
4	102	.385	102	.384	102	.489
5	61	.209	61	.437	61	.479
6	16	.561	16	.617	16	.474
Sept						
7	62	.278	62	.526	62	.469
8	326	.228	326	.565	326	.458
9	198	.279	198	.560	198	.513
Oct						
9	45	.112	45	.380	45	.656
10	87	.253	87	.387	87	.388

Model 7: Dependent variable from the objective yield 6-inch plot. X8 and X15 are from the objective yield 6-inch plot. X12A, X9A, X4A, X10A, X16A, X13A and X14A are estimated variables. These variables are based on regression equations developed from the destructive 6-inch plot, and are functions of X8 and X15.

Model 8: Dependent variable from the objective yield 6-inch plot. X8, X15, and X13 are from the objective yield 6-inch plot. X12A, X9A, X4A, X10A, X16A, and X14A are estimated variables and are functions of X8, X15 and X13.

Model 9: Dependent variable from the objective yield 6-inch plot. X8, X15, and X14 are from the objective yield 6-inch plot. X12A, X9A, X4A, X10A, X16A and X13A are estimated variables and are functions of X8, X15 and X14.

Table 9: Relative Importance of Independent Variables in Adjusted Destructive Regression Equations Illinois 1978-1980*

Var	MATURITY CATEGORIES 1		2		3		4		5		6		7		8		9		9		10	
	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9	Mod 8	Mod 9
X4	---	---	---	---	---	---	---	(316.97)	(1.00)	2.02	1.62	---	---	---	2.09	2.33	(89.59)	(6.71)	---	---	---	---
X8	---	1.00	---	1.06	---	---	---	57.10	---			---	---	---	---	---	---	---	1.00	---	---	1.00
X9	---	---	---	4.93	---	---	1.00	---	---	1.00	1.00	---	---	1.02	(2.90)	(21.51)	61.48	---	---	1.00	15.33	1.72
X10	11.83	---	---	---	---	---	---	---	---			1.00	---	---	---	---	---	---	---	---	---	---
X12	---	---	---	1.00	---	1.18	---	---	---	4.40	(3.43)	(1.65)	---	1.05	---	---	---	---	---	(3.69)	1.00	(3.53)
X13	---	1.68	---	---	---	1.00	12.75	1.00	---	---	---	---	(1.27)	---	1.00	---	47.14	1.00	(4.33)	---	---	---
X14	(15.21)	---	---	(11.10)	---	(1.24)	24.02	---	---	---	---	---	1.00	---	---	---	---	---	---	---	10.61	---
X15	1.00	(1.78)	---	---	1.00	---	---	72.49	---	---	---	---	---	1.00	---	1.00	1.00	---	---	---	---	---
X16	---	---	(1.00)	4.81	(4.31)	---	(35.44)	124.57	---	(4.65)	---	---	---	(2.67)	---	2.63	---	---	---	---	---	---

* The variable which is least important in the regression equation is given a value of 1.00. The other variables are assigned values relative to the least important variable. The most important variable is in parenthesis. The value for the variable X12 are underlined since this variable is pods with beans per plant.

CONCLUSIONS

Comparisons of per plant counts in Illinois in 1980 indicate that there is no significant difference in the counts obtained from the two methods. Moreover, there was no significant handling effects or counting error effects in 1980. This was not the case in Illinois in 1978 and 1979. No definitive reasons for this method by year interaction could be found.

The forecasting ability of the destructive procedure does not forecast pods per plant at an acceptable level. Several methods of adjusting the destructive procedure were examined. While these methods were improvements over the destructive method, they were not superior to the nondestructive models. In addition, these models required trade offs. While the plants in the destructive six-inch plots can be carried out of the field to ease enumerator burden, nondestructive additional counts must be made in the nondestructive three-foot plot. Moreover, the advantage of not counting the same plants each month in order to eliminate any possible handling effects is tempered by the fact that a handling effect may be introduced into the three-foot section. Thus, it is not recommended that the destructive counting method be adopted in the operational program.

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APPENDIX I

Maturity Categories

Maturity categories are calculated by unit. The purpose of the categories is to group units by maturity with the intention of improving the forecasting models. Calculation of the maturity categories is based on an enumerator observed maturity stage and per plant counts. Maturity stage is observed in the three-foot section. Listed below are the maturity stage and maturity category descriptions. Additional information can be found in the Objective Yield Survey Enumerators Manual and the Objective Yield Supervising and Editing Manual.

Soybean Objective Yield Maturity Stages Determined by Enumerators

Maturity Stage	Description
1	Plants still in bloom stage. Any pods found are still green with little or no seed development.
2	Very few blooms. Most pods still filling and leaves are still green.
3	Leaves turning yellow. Almost all pods filled and some ripening.
4	All leaves have turned yellow and some have fallen. Pods full sized and changing from green to brown color. Beans not yet firm.
5	Pods brown and easily opened. Beans brown and have shrunken. Most leaves have been shed.
6	Pods brown and ready to combine. Beans very hard.

Soybean Objective Yield Assigned Maturity Categories

Maturity Category	Description 1/
0	No plants were present in either row of the two 6-inch row sections per unit.
1	No pods are present and less than 60% of the plants in the 6-inch row sections have blooms.
2	At least 60% of the plants in the 6-inch row sections have some blooms but no pods were counted. Also, the ratio of blooms to nodes is not greater than one.
3	a) If pods were counted, the number of pods was not larger than the number of blooms. b) If no pods were counted, the ratio of blooms to nodes is larger than one.
4	The ratio of pods to total fruit (blooms plus pods) is between .50 and .75, and the ratio of pods with bean (if any) to fruit is less than or equal to .01.
5	The ratio of pods to total fruit is larger than .75, or the ratio of pods with beans to total fruit is between .01 and .10.
6	The ratio of pods with beans to total fruit is between .10 and .30.
7	The ratio of pods with beans to total fruit is between .30 and .50.
8	The ratio of pods with beans to total fruit is larger than .50 and the leaves have not yet started to turn yellow.
9	Leaves have started to turn yellow but no leaves have been shed (Maturity State 3).
10	Leaves have all turned yellow and are starting to fall from the plants (Maturity Stage 4).
11	At least half of the leaves have been shed by the plants. (Maturity Stages 5 and 6).

1/ Brief approximation of each category determination.

A P P E N D I X   II

Regression Independent Variables

Variables Considered When Selecting "Best" Set of Predicting Variables

Variable	Maturity Category 1/	Description
X15	1-11	Number of plants in both 3-ft and 6-inch sections, adjusted to 18 square feet.
X8	1-11	$(X15)^2$
X12	1-11	Pods with beans per plant.
X9	1-3	Mainstem nodes per plant.
	4-11	$(X12)^2$
X4	1-3	Nodes with fruit buds only per plant.
	4-11	Pods and dried flowers per plant.
X10	1-11	Blooms, pods and dried flowers per plant, August and September only.
X13	1-11	Mainstem nodes with fruit, per plant.
X14	1-11	Lateral branches with fruit per plant.
X16	1-11	Lateral branch nodes with fruit per plant.

The following variables were considered when adjusting equations:

DIFFPL	(6-inch objective yield number of plants -- 6-inch destructive plot number of plants)
DIFFPL2	$(DIFFPL)^2$
DIFFNOD	(X13OY-X13RES)
DIFFLAT	(X14OY-X14RES)

NOTE: A suffix of OY indicates the observation was made in objective yield 6-inch plot.

A suffix of RES indicates the observation was made in destructive 6-inch plot.

A suffix of A indicates an adjusted value (i.e., the estimate of the variable if the variable had been counted).

1/ See Appendix I for a description of maturity categories.

APPENDIX III

Regression Equations

Table 1: Regression Equations for Illinois, 1980

August 1980, Illinois

Maturity Category 1

Model 1: 20.5644 + 28.9108 (X9) + 1.1177 (X4) - 21.7475 (X10)
Model 2: 24.1866 + 17.6013(X9) - 1.7172(X4) - 9.1625(X10) + 66.9512(X14)
Model 3: 50.1532 - .0106(X8) - 9.9399(X10)
Model 4: 11.3277 + 1.9595(X4) - 3.4393(X10)

Maturity Category 2

Model 1: 160.8273 - 5.2553(X15) + .0439(X8) + 1.5801(X4)
Model 2: 40.1685 - .008(X8) - 2.7044(X9) + 1.9586(X4) + .4949(x10) - 19.1598(X14) + 10.4651(X16)
Model 3: 32.6978

Model 4: 2.3360 + 1.7481(X15) - .0253(X8) - 3.9985(X9) + 1.5984(X4) + .1361(X14) + 11.1894(X16)

Maturity Category 3

Model 1: 52.5023 - 1.01079(X15) + .0054(X8) - 2.0511(X9) - 1.0711(X4) + .8147(X10)

Model 2: 82.4035 - 1.7666(X15) + .01084(X8)
Model 3: 62.4071 - 1.4021(X15) + .0086(X8) + .2116(X10)
Model 4: 29.2205 - 1.3314(X15) + .0084(X8) - 31.0112(X12) + 2.8414(X9) + 1.8095(X4) + 23.3291(X14) - 3.9769(X16)

Maturity Category 4

Model 1: 104.4087 - 3.6247(X15) + .0333(X8) + .8102(X10) - 2.2105(X13) - 4.9296(X14) + .2885(X16)
Model 2: 120.9232 - 4.7498(X15) + .0464(X8) + .466(X10) - 3.2394(X14)
Model 3: 92.2106 - 1.5434(X15) + .0127(X8) + .138(X9) - .4388(X4) + 1.1482(X10) - 5.3426(X13) - 17.4558(X14) + 3.3931(X16)
Model 4: 70.6592 - 2.6587(X15) + .0254(X8) - 7.6061(X12) + 1.2245(X9) + .5126(X10) - 3.7833(X14) + 1.168(X16)

Maturity Category 5

Model 1: 70.374 - 1.2475(X15) + .0084(X8) - .4715(X12) + .0468(X9) - .1987(X10) + .9153(X13) + 1.4605(X14)
Model 2: 90.8256 - 3.0647(X15) + .032(X8) + .1266(X10)
Model 3: -.343 + 2.4946(X15) - .0373(X8) - .9758(X13) + 3.9395(X14)
Model 4: 32.9121 - 1.3792(X15) + .014(X8) - 1.5377(X12) + .1222(X9) - .5732(X4) + .8587(X10) + 2.8102(X14)

Continued. . .

Table 1 continued. . .

<u>September 1980, Illinois</u>

Maturity Category 7

Model 1: $81.0461 - 4.045(X15) + .0392(X8) + 1.9407(X12) - .0134(X9) + .8244(X13) - 7.9831(X14)$

Model 2: $56.1382 - 1.0457(X15) + .0061(X8) + .4168(X12) + .2566(X4) - 1.7983(X13) - 7.4668(X14) + 1.4956(X16)$

Model 3: $24.8294 - .7251(X15) + 2.6974(X13)$

Model 4: $-7.6375 + .5977(X12) - .0062(X9) - .3021(X4) + .3594(X10) + 1.0647(X13) - 1.173(X14) + 1.3373(X16)$

Maturity Category 8

Model 1: $63.6038 - 1.5286(X15) + .0081(X8) + .2297(X12) + .6056(X13) + 1.7036(X14) - .7109(X16)$

Model 2: $40.8745 - .5148(X15) + .0020(X8) + .9605(X12) - .0044(X9) - 7.6761(X4) + 7.5151(X10) - 1.0949(X13) - 4.1307(X14) + 1.0449(X16)$

Model 3: $38.1058 - .7678(X15) + .0036(X8) + 1.331(X13)$

Model 4: $5.3825 - 0.867(X15) + .7659(X12) - .079(X4) + .5185(X13) - 2.0634(X14) + .5738(X16)$

Maturity Category 9

Model 1: $75.3233 - 1.5549(X15) + .0103(X8) - 1.1769(X14) + .5659(X16)$

Model 2: $54.5237 - .8683(X15) + .0039(X8) + .4618(X12) + .0019(X9) - .3234(X4)$

Model 3: $58.2077 - 1.3983(X15) + .01(X8) + 1.7057(X12) - 1.2463(X4) + 5.6075(X14) - .8525(X16)$

Model 4: $14.8674 - .2109(X15) + .0009(X8) + 1.1449(X12) + .00329(X9) - .7594(X4) + .8485(X13)$

<u>October 1980, Illinois</u>

Maturity Category 9

Model 1: $8.7043 - .0018(X8) - .0005(X9) + 2.0303(X13)$

Model 2: $-65.6405(X12) - .0376(X9) + .7807(X13)+2.4009(X15) -.0216(X8)+1.7255(X12)$

Model 3: $18.7398 - .0038(X8) - .0232(X9) + .7114(X4) + 7.6139(X14)$

Model 4: $-15.9438 + .4245(X15) - .0035(X8) + 1.3055(X12) - .0094(X9) + .0481(X4)$

Maturity Category 10

Model 1: $40.079 - 1.2793(X15) + .0109(X8) + 2.5464(X12) - .0171(X9) - .9254(X4) - .9049(X13)$

Model 2: $60.7377 - 2.9006(X15)+ .0312(X8) + 2.4513(X12) - .0219(X9) - .8999(X13) - 1.3266(X16)$

Model 3: $23.8980 - .6060(X15) - .0079(X9) + 1.1744(X4) - 9.2665(X14) + 1.7298(X16)$

Model 4: $.6165 - .0029(X8) + .3846(X12) - .0051(X9) + .8771(X4)$

Table 2: Regression Equations for Illinois, 1978, 1979 and 1980 Combined

August

Maturity Category 1

Model 1: 51.4880 - 1.0624(X15) + .0065(X8) + 1.5806(X9) - 15.7112(X10) + 20.6913(X13) + 50.7006(X14) + 2.0534(X16)
Model 2: 58.067 - 1.178(X15) + .0077(X8) + .7592(X9) - 6.3512(X13) + 70.0323(X14)
Model 3: 37.9285 - .2931(X15) - 1.5233(X10) + 67.3927(X14) - 20.5912(X16)
Model 4: 24.0850 - .19(X15) + .5577(X9) + .6961(X4) - 3.4476(X10) + 31.2286(X14)

Maturity Category 2

Model 1: 126.1725 - 3.6842(X15) + .0299(X8)
Model 2: 59.7111 - 1.3233(X15) + .0074(X8) + .7798(X9) + .302(X10) - 3.7787(X14)
Model 3: 39.1119 - 2.4704(X13)
Model 4: 31.383 - .0023(X8) + 1.2743(X4) - .4517(X10) - 1.4229(X13) + 8.2871(X16)

Maturity Category 3

Model 1: 57.8685 - 1.1939(X15) + .0067(X8) - 2.2(X12) + .7902(X9) + .3841(X10) - 1.2968(X13)
Model 2: 64.7164 - .9513(X15) + .0048(X8) + .2254(X10) -1.2426(X13) -3.4377(X14) + 1.1171(X16)
Model 3: 63.9983 - 1.4964(X15) + .0094(X8) + 1.0653(X9)
Model 4: 14.8498 - .2904(X15) + 2.0376(X4) + 1.6824(X13) + 12.8777(X14) -1.3328(X16)

Maturity Category 4

Model 1: 79.5039 - 2.1499(X15) + .0175(X8) - .0748(X9) + .4492(X4) - .8587(X13) + .3885(X16)
Model 2: 99.3242 - 2.7625(X15) + .0228(X8) + .71374(X4) - .4297(X10) - 4.5777(X14) + .5662(X16)
Model 3: 82.3262 - 1.2223(X15) + .0082(X8) + .4930(X10) - 3.5068(X13) -7.8413(X14) + 1.9826(X16)
Model 4: 59.6423 - 1.6727(X15) + .0142(X8) + .2089(X4) + .2277(X10) - .463(X13) - 4.4804(X14) + 1.3207(X16)

Maturity Category 5

Model 1: 62.5120 - .6084(X15) + .0158(X9) + .4113(X4) - .4570(X10) -2.500(X14) + .9237(X16)
Model 2: 85.9402 - 2.42(X15) + .0219(X8) - 1.0112(X12) - .1223(X9) + .2626(X4) - .1413(X10)
Model 3: 25.0344 + 1.2140(X15) - .0225(X8) - .654(X13) + 4.7438(X14) - .6336(X16)
Model 4: 19.545 - .6249(X15) + .0057(X8) - 1.0049(X12) + .406(X10) + 2.7124(X14)

Continued. . .

Table 2 continued. . .

September

Maturity Category 6

Model 1: 173.1539 - 5.7939(X15) + .0459(X8) + 2.0673(X12) - .0283(X9) - .9943(X13)
Model 2: 63.0288 - 1.4576(X15) + .0092(X8) + 5.344(X14)
Model 3: 23.8039 - .0056(X8) - .0186(X9) + .2489(X4) - .8815(X13) - 11.1631(X14) + 4.4574(X16)
Model 4: 5.3805 - .004(X8) + 1.1777(X12) + .773(X16)

Maturity Category 7

Model 1: 64.47 - 2.5028(X15) + .0242(X8) + 1.4511(X12) - .0046(X9) + 1.0579(X4) - 1.1743(X10) - 5.6406(X14)
Model 2: 51.4785 - .0799(X15) + .0044(X8) - .3373(X12) + .0051(X9) + 1.6396(X4) - 1.511(X10) - .4335(X13) - 2.1185(X14) + .813(X16)
Model 3: 37.1235 - .6868(X15) + .0036(X8) + .354(X12)
Model 4: -4.8077 + .7449(X12) - .0049(X9) + .045(X10) + .7125(X13) -1.6382(X14) + 1.2081(X16)

Maturity Category 8

Model 1: 68.7508 - 1.4967(X15) + .0086(X8) + .6852(X12) - 11.4875(X4) + 11.2698(X10) - .2687(X13) + 1.959(X14) - .9508(X16)
Model 2: 64.6147 - 1.4703(X15) + .0103(X8) + .434(X12) + 2.614(X4) - 2.7487(X10)
Model 3: 39.5348 - .7225(X15) + .0037(X8) + .5574(X12) - .0024(X9) - .2877 (X16)
Model 4: 2.7935 - .265(X15) + .0019(X8) + .7895(X12) - .0023(X9) + .759(X13) - .6785(X14) + .5586(X16)

Maturity Category 9

Model 1: 75.3857 - 1.7498(X15) + .0123(X8) + .8804(X12) - .0017(X9) - .439(X4) - .4304(X13)
Model 2: 57.3604 - .9428(X15) + .0044(X8) + .1494(X12) + .0014(X9) - .2201(X16)
Model 3: 65.8216 - 1.642(X15) + .012(X8) + 1.3519(X12) - .7608(X4) - .4205(X13) + 5.5023(X14) - 1.603(X16)
Model 4: 3.0321 - .0286(X15) + 1.0502(X12) + .0012(X9) - .3649(X4) + .5843(X13)

Continued. . .

Table 2 Continued. . .

<u>October</u>

Maturity Category 9

Model 1: $40.6487 - 1.5244(X15) + .01284(X8) + 1.0714(X12) - .0059(X9)$
Model 2: $53.3087 - 1.4718(X15) + .0116(X8) - .0045(X9) + .4054(X4) - 4.7562(X14) + 2.7911(X16)$
Model 3: $19.4652 + .3603(X12) + .0044(X9) - .5611(X13) - 1.2834(X16)$
Model 4: $-3.1927 + .8234(X12) + .1437(X4) + .3651(X13) + .4834(X14) - .4362(X16)$

Maturity Category 10

Model 1: $35.4053 - .7920(X15) + .0057(X8) + 1.2567(X12) - .0113(X9) - .2946(X4) - .2281(X13)$
Model 2: $44.8747 - .7234(X15) + .0047(X8) + .1798(X12)$
Model 3: $39.5548 - 1.0003(X15) + .0058(X8) - .2317(X12) - .0119(X9) + 1.1473(X4) - 5.8338(X14) + 1.5672(X16)$
Model 4: $2.3254 + .1650(X15) - .0021(X8) + .9997(X12) - .0881(X4) + .5143(X16)$

Table 3: Regression Equations for Adjusted Per Plant Counts
Illinois 1978, 1979 and 1980

Maturity Category 1

X12A = X12
X9A = 8.56320 - .04902(X15) + .00039(X8) + .59559(X13) + 2.42840(X14)
X4A = 6.98755 - .07536(X15) + .00054(X8) - .08694(X13) - .68420(X14)
X10A = .04009 + .00034(X15) + 1.55322(X13) + 2.36468(X14)
X16A = .06209 + .00156(X15) + .07202(X13) + 1.31070(X14)

Maturity Category 2

X12A = -.09899 + .00118(X15) + .04125(X13) - .06410(X14)
X9A = -.14664 + .11220(X15) - .00067(X8) + .57986(X13) + 3.20142(X14)
X4A = 1.48601 + .13772(X15) - .00147(X8) - .294333(X13) + 1.19754(X14)
X10A = -2.10732 + .18248(X15) - .00229(X8) + 2.33347(X13) + 3.1696(X14)
X16A = -.39986 - .01537(X15) + .00012(X8) + .11040(X13) + 2.1947)X14)

Maturity Category 3

X12A = -3.27591 + .08265(X15) - .00064(X8) + .15924(X13) + .32996(X14)
X9A = -3.59578 + .21775(X15) - .00175(X8) + .82937(X13) + 1.19940(X14)
X4A = 2.81634 + .05000(X15) - .00048(X8) - .2077(X13) + .31936(X14)
X10A = -18.61436 + .60354(X15) - .00545(X8) + 4.18217(X13) + 5.57800(X14)
X16A = -3.92926 + .09550(X15) - .00076(X8) + .20872(X13) + 2.43772(X14)

Maturity Category 4

X12A = -5.81335 + .09375(X15) - .00064(X8) + .45003(X13) + .38508(X14)
X9A = $(X12A)^2$
X4A = -4.12608 - .11343(X15) + .00201(X8) + 3.97491(X13) + 4.46683(X14)
X10A = 2.70572 - .40836(X15) + .00414(X8) + 4.29461(X13) + 7.49205(X14)
X16A = .64626 - .13869(X15) + .00121(X8) + .33365(X13) + 3.04917(X14)

Maturity Category 5

X12A = -11.35170 + .29897(X15) - .00325(X8) + .59281(X13) + 1.30741(X14)
A9A = $(X12A)^2$
X4A = -12.74185 + .58310(X15) - .00990(X8) + 4.69542(X13) + 9.02169(X14)
X10A = -5.77926 + .65436(X15) - .01070(X8) + 4.34299(X13) + 11.20926(X14)
X16A = - 7.20313 + .02427(X15) .00074(X8) + .63072(X13) + 4.73422(X14)

Maturity Category 6

X12A = 7.03065 - .45438(X15) + .00363(X8) + 1.35639(X13) + 1.99500(X14)
X9A = $(X12A)^2$
X4A = -65.66386 + 3.03823(X15) - .03328(X8) + 3.23281(X13) + 16.69923(X14)
X10A = -38.43146 + 1.12138(X15) - .01258(X8) + 5.10937(X13) + 13.64801(X14)
X16A = 7.11153 - .84560(X15) + .00910(X8) + 1.05046(X13) + 3.71035(X14)

Maturity Category 7

$X12A = 18.24820 - .09718(X15) - .00115(X8) + .11630(X13) + 8.29737(X14)$
$X9A = (X12A)^2$
$X4A = 29.85010 + .10671(X15) - .00425(X8) + .40047(X13) + 18.68392(X14)$
$X10A = 29.76309 + .10331(X15) - .00426(X8) + .51703(X13) + 18.71877(X14)$
$X16A = 4.41505 - .11358(X15) + .0070(X8) - .13964(X13) + 3.49042(X14)$

Maturity Category 8

$X12A = 40.17914 - .63278(X15) + .00409(X8) - .04957(X13) + 8.75547(X14)$
$X9A = (X12A)^2$
$X4A = 57.24637 - .83209(X15) + .00521(X8) - .08890(X13) + 12.77072(X14)$
$X10A = 57.41194 - .83783(X15) + .00524(X8) - .08317(X13) + 12.77109(X14)$
$X16A = 6.02646 - .20860(X15) + .00123(X8) + .01290(X13) + 4.07644(X14)$

Maturity Category 9 (September)

$X12A = 39.67036 - .55791(X15) + .00241(X8) + .40275(X13) + 9.22936(X14)$
$X9A = (12A)^2$
$X4A = 49.60834 - .74202(X15) + .00340(X8) + .30348(X13) + 11.43133(X14)$
$X10A = 49.60834 - .74202(X15) + .00340(X8) + .30348(X13) + 11.43133(X14)$
$X16A = 4.82958 - .18577(X15) + .00101(X8) + .0866(X13) + 4.10217(X14)$

Maturity Category 9 (October)

$X12 = 19.43959 - .20196(X15) - .00114(X8) + .95220(X13) + 10.82506(X14)$
$X9A = (X12A)^2$
$X4A = 21.65867 - .29236(X15) - .00016(X8) + 1.09107(X13) + 11.68003(X14)$
$X16A = .38660 - .055145(X15) + .16126(X13) + 3.85699(X14)$

Maturity Category 10

$X12A = 31.88660 - .47560(X15) + .00378(X8) + .46283(X13) + 5.73245(X14)$
$X9A = (X12A)^2$
$X4A = 32.02068 - .44870(X15) + .00392(X8) + .45280(X13) + 6.73965(X14)$
$X16A = 1.48279 - .04899(X15) + .00014(X8) + .01338(X13) + 3.24188(X14)$

Table 4: Adjusted Regression Equations for Illinois 1978, 1979, 1980 Combined

<u>August</u>

Maturity Category 1

Model 5: 242.7658 - .2327(X15OY) - 410.3058(X14OY) - 29.2321(X9A) + .5728(X4A) + 327.8697(X16A)

Model 6: 22.3672 - .1694(X15RES) + 3.7927(X13RES) + .7870(X9RES) - 4.3252(X10RES) - 1.1973(DIFFPL) + .0485(DIFFPL2) - 1.4062(DIFFNOD) + 21.8451(DIFFLAT)

Maturity Category 2

Model 5: 37.1653 + 27.0014(X14OY) - 52.0767(X12A) - 3.6503(X9A)

Model 6: 19.6419 + 14.2665(X14RES) + 1.3469(X4RES) - 3.0862 (X16RES) - 2.1380(DIFFPL) + .0847(DIFFPL2) + 2.3517(DIFFNOD) + 7.3241(DIFFLAT)

Maturity Category 3

Model 5: 12.2961 - .2107(X15OY) + 8.6620(X14OY) - 9.3392(X12A) + .6979(X10A)

Model 6: 44.3267 - .9706(X15RES) + .0056(X8RES) + 6.4593(X14RES) + .3375 (X9RES) + .1974(X10RES) - 1.0744(DIFFPL) - .0965(DIFFPL2) + 2.4722(DIFFNOD) + 9.3943(DIFFLAT)

Maturity Category 4

Model 5: 37.7626 - .3757(X15OY) = 2.5239(X16A)

Model 6: 60.5635 - 1.0918(X15RES) + .0074(X8RES) - 1.7767(X13RES) + 1.9088(X14RES) + .3453(X10RES) + .7131(X16RES) - .8734(DIFFPL) + 2.0934(DIFFNOD) + 4.7813(DIFFLAT)

Maturity Category 5

Model 5: - .2090 - .1026(X15OY) - .1300(X9A) + .6437(X4A)

Model 6: .9893 - .0015(X8RES) + 2.5976(X13RES) + 6.3721(X14RES) - .0959(X4RES) - .5031(DIFFPL) + 3.9248(DIFFNOD) + 2.0447(DIFFLAT)

Maturity Category 6

Model 5: 21.0444 + 4.3627(X12A) - .8282(X4A)

Model 6: 191.450 - 9.7146(X15RES) + .1039(X8RES) + 5.6028(X13RES) - 8.5616(X14RES) - .3495(X12RES) + .1044(X9RES) - 3.0764(X10RES) + 3.2659 (X4RES) - 3.3970(X16RES) - 1.1089(DIFFPL) + .1148(DIFFPL2) + 4.0835(DIFFNOD) - 2.9587(DIFFLAT)

Continued. . .

Table 4 continued. . .

September

Maturity Category 7

Model 5: 34.8502 - .9975(X15OY) + 1.0725(X13OY) - 10.4319(X12A) + 4.8580(X4A)
Model 6: 9.7482 - .0597(X15RES) + .0040(X8RES) + 2.6708(X13RES) - .2001((X12RES)
+ .0048 (X9RES) + .4574(X16RES) - .9819(DIFFPL)
+ .0438 (DIFFPL2) + 2.8187(DIFFNOD) + 4.3626(DIFFLAT)

Maturity Category 8

Model 5: - 3.4396 - .2157(X15OY) + .0010(X8OY) + 2.5302(X13OY) + .0072(X9A)
Model 6: 4.0712 - .3861(X15RES) + .0018(X8RES) + 2.2234(X13RES)
+ 3.4191(X14RES) + .1943(X12RES) - .0524(X10RES) + .2422(X16RES)
- .1936(DIFFPL) + .0377(DIFFPL2) + 2.2837(DIFFNOD) + 6.8132(DIFFLAT)

Maturity Category 9

Model 5: - 9.4773 + 2.7036(X13OY) - 1.3496(X12A) + .0038(X9A) + 1.2376(X10A)
Model 6: 8.2988 - .5481(X15RES) + .0038(X8RES) + 2.0265(X13RES) + 6.0672(X14RES)
+ .7567(X12RES) - .4525(X10RES) - .5668(X16RES) + 2.5118(DIFFNOD)
+ 5.8483(DIFFLAT)

October

Maturity Category 9

Model 5: -4.7223 + 2.1982(X13OY) + .0026(X9A) + .2043(X4A)
Model 6: -27.2073 + .7985(X15RES) - .0071(X8RES) + 2.8789(X13RES)
- .1112 (X12RES) + .0026(X9RES) + .3005(X4RES) - .7631(DIFFPL)
- .1806(DIFFPL2) + 3.2774(DIFFNOD) + 3.7316(DIFFLAT)

Maturity Category 10

Model 5: - 58.4120 + 1.0377(X13OY) + 6.2239(X12A) - .0360(X9A) - 2.4444(X4A)
Model 6: .7782 - .2340(X15RES) + 1.9833(X13RES) + 2.9763(X14RES)
- 1.1280(X12RES) - .0048(X9RES) + 1.5471(X4RES) + .1546(X16RES)
+ .2283(DIFFPL) - .1268(DIFFPL2) + 2.3094(DIFFNOD) + 4.3767(DIFFLAT)

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