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REPORT ON 1978 LANDSAT YIELD AND PRODUCTION STUDY AS IT PERTAINS TO THE OBJECTIVE YIELD PROGRAM

By

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Report on 1978 LANDSAT Yield and Production Study
as it Pertains to the Objective Yield Program

Introduction

The 1978 LANDSAT Yield and Production Study (LYPS) was conducted in Iowa for corn and soybeans. The purpose of the research was to obtain yield and LANDSAT data sets so that possible relationships could be explored. If satellite imagery is related to yield or some component of yield, it might be possible to improve final yield estimates by incorporating LANDSAT data in a double sampling approach. The New Techniques Section has been doing research on improving acreage estimates with LANDSAT for several years. Some good gains in precision have been documented. In a recent paper by Wigton and Huddleston, a modest improvement in yield estimate precision was demonstrated for corn and soybeans in a 1975 Illinois data set.

This report stems from the yield side of LYPS. In the process of computing field level yield estimates for the research, some of the objective yield estimating procedures were examined. The purpose of this report is to pass along some of the results and suggest some changes which may be needed.

Yield Data Set

A rather extensive objective yield data set was obtained. In LYPS, we were primarily interested in estimating the biological yield at the field level. To obtain better field level inference, the number of final pre-harvest samples was increased from one to four in all corn and soybean objective yield fields in Iowa. The only difference between the research units and the regular objective yield units was that counts in the 6-inch sections were not done for soybeans. Additionally, the post-harvest interview (Form D) was done for all objective yield fields. Of the original 240 corn samples and 170 soybean samples, we ended up with 166 corn and 126 soybean samples which had both objective and farmer reported yields. Most of these fields had all 8 units but a few only contained the two regular objective yield units.

Outline Form

In an effort to keep this report as short and concise as possible, an outline form has been used. There is one section for soybeans and another for corn. The longer tables appear in the Appendix and are numbered using a prefix of "A."

Outline

I. SOYBEANS

A. How Final Soybean Objective Yield Estimate is Computed.

1. Computation of number of pods per unit area.

a. Computation of mean and CV_1^2 for Form B pods per unit area.

b. Computation of mean and CV_2^2 for Form C pods per unit area.

2. Computation of weight per pod at 12.5% moisture.

B. Comparison of Net Yield (Using Only Form C and Form E Data) and Farmer Reported Yield.

1. Estimation of mean net yield at field level.

2. Estimation of variance of mean biological field yield.

3. Calculated means and variances.

C. Assumptions Used in Estimating Means and Variances in Regular Objective Yield Program.

1. Row widths within a sample are equal.

2. Mean weight per pod is the same for both units within a sample.

3. Product of two components in Section I.A. is a single random variable.

II. CORN

A. How Final Corn Objective Yield Estimate is Computed.

1. Computation of number of ears per unit area.

2. Computation of grain weight per ear at 15.5% moisture.

B. Comparison of Net Yield and Farmer Reported Yield.

1. Estimation of mean net yield at the field level.

2. Estimation of variance of mean biological field yield.

3. Calculated means and variances.

C. Assumptions Used in Estimating Means and Variances in Regular Objective Yield Program.

1. Row widths within a sample are equal.

2. Shelling fraction is the same for ears 3 and 4 of both units as it is for all ears harvested in both units.

3. Mean gross sample level yield is equal to the product of two components.

4. Variance of state yield is calculated using the formula presented in Section I.B.3.

D. Effect of Using 2-Row Ear Counts Versus 1-Row Ear Counts at Field and State Level.

III. CONCLUSIONS

I. SOYBEANS

A. How Final Soybean Objective Yield Estimate is Computed.

The following procedure is based on the S&E Manual and discussions with Methods Staff personnel. Similar notation to that found on Pages 15D-8 and 15D-9 of the S&E Manual is used.

$$\begin{pmatrix}\text{Gross yield per unit}\\ \text{area at 12.5\% moisture}\end{pmatrix} = \begin{pmatrix}\text{No. of pods}\\ \text{per unit area}\end{pmatrix}\begin{pmatrix}\text{Weight per pod}\\ \text{at 12.5\% moisture}\end{pmatrix}$$

1. Computation of number of pods per unit area.

$$\begin{pmatrix}\text{No. of pods}\\ \text{per unit area}\end{pmatrix} = \left(\frac{V_2X_1 + V_1X_2}{V_1 + V_2}\right)$$

where: X_1 = Estimated number of pods per unit area from Form B

X_2 = Estimated number of pods per unit area from Form C

V_1 = Squared sample level coefficient of variation (CV_1^2) for X_1

V_2 = Squared sample level coefficient of variation (CV_2^2) for X_2

a. Computation of mean and CV_1^2 for Form B pods per unit area.

X_1 is calculated for each unit.

$X_{1i} = A_iB_i \quad i = 1, 2$ units

where: $$A = \frac{\begin{pmatrix}\text{Sum of pods in row 1 and}\\ \text{row 2 of 6-inch section}\end{pmatrix}}{\begin{pmatrix}\text{Sum of plants in row 1 and}\\ \text{row 2 of 6-inch section}\end{pmatrix}}$$

$$B = \frac{\begin{pmatrix}\text{Sum of plants in row 1 and row 2}\\ \text{of 6-inch and 3-foot sections}\end{pmatrix}\text{(4 rows)}}{\text{(3.5 feet) (width of 4 row spaces) (2 rows)}}$$

$$X_1 = \frac{\sum_{i=1}^{2} X_{1i}}{2}$$

$$V_1 = \frac{\sum_{i=1}^{2} (X_{1i}-X_1)^2}{2X_1^2} = \left(\frac{X_{11}-X_{12}}{X_{11}+X_{12}}\right)^2$$

b. Computation of mean and CV_2^2 for Form C pods per unit area.

X_2 is calculated for each <u>sample</u>.

$$X_2 = \frac{(W_1+W_2)(X_c)(8 \text{ rows})}{(W_c)(\text{Width of 8 row spaces})(6 \text{ feet})}$$

where: W_1 = Weight of pods from row 1, unit 1

W_2 = Weight of pods from row 1, unit 2

W_c = Weight of pods from row 1 of the unit counted in the lab

X_c = Number of pods from row 1 of the unit counted in the lab

It has been shown in some unpublished notes by Bond that the variance of X_2 is equivalent to

$$V(X_2) = \left(\frac{X_2(W_1-W_2)}{(W_1+W_2)}\right)^2$$

This is true only if the four row width in unit 1 is the same as in unit 2. It follows that

$$V_2 = \left(\frac{W_1-W_2}{W_1+W_2}\right)^2$$

2. Computation of weight per pod at 12.5% moisture.

This component is derived from Form C.

$$\begin{pmatrix}\text{Weight per pod} \\ \text{at 12.5\% moisture}\end{pmatrix} = \left(\frac{W_c W}{X_c(W_1+W_2)}\right)\left(\frac{100- \text{ \% moisture}}{87.5}\right)$$

where: W_1, W_2, W_c and X_c are defined as in Section I.A.1.b.

W = Threshed weight of beans from row 1 of both units

% moisture = Percent moisture of beans immediately after threshing

To obtain biological (gross) yield per acre, the gross yield per unit area at 12.5% moisture is expanded to the acre level and expressed in bushels. As presented here, the units are (grams/ft^2) so (bushels/acre) would be obtained by multiplying by 43,560 and dividing by 453.59 and 60. Net yield is obtained by subtracting a harvest loss estimate based on two units in a half sample of all the objective yield fields. The formula for computing the harvest loss is on page 15D-9 of the S&E Manual.

B. Comparison of Net Yield (Using Only Form C and Form E Data) and Farmer Reported Yield.

1. Estimation of mean net yield at field level.

Since no 6-inch counts were made in the research samples, the field biological yield was computed separately for each unit as follows:

$$YLDPAC = \left(\frac{\sum_{i=1}^{4} (Y_{1i}+Y_{2i})}{8} \right) (\text{Adjustment factor})$$

where: $i = 1, 2, \ldots, 4$ samples

Y_{1i} = unit 1 yield

$$= \left(\frac{WW_1}{W_1+W_2} \right) \frac{(4 \text{ rows})(100- \% \text{ moisture})}{(\text{width of 4 rows})(3 \text{ feet})(87.5)}$$

Y_{2i} = unit 2 yield

$$= \left(\frac{WW_2}{W_1+W_2} \right) \frac{(4 \text{ rows})(100- \% \text{ moisture})}{(\text{width of 4 rows})(3 \text{ feet})(87.5)}$$

Adjustment factor converts from grams/ft.^{2} to bushels/acre.

Notice that the <u>sample</u> mean $(Y_1+Y_2)/2$ is equivalent to

$$(X_2) \left(\begin{matrix} \text{Weight per pod at} \\ 12.5\% \text{ moisture} \end{matrix} \right) (\text{Adjustment factor})$$

only if the 4 row measurements are the same for both units. Net yield per acre was obtained for all fields with harvest loss measurements as follows:

NYLDPAC = YLDPAC - HARVLOSS

where: HARVLOSS = objective yield harvest loss computation in 2 units per field.

2. Estimation of variance of mean biological field yield.

The additional research samples were laid out from the other three corners of the field. Assuming that the fields are rectangular, the design is two random units in each quarter of the field. Since the 8 units are not independent, the within field variance was calculated using the well known stratified variance formula

$$V(\hat{\bar{y}}_{st}) = \frac{1-f}{n} \sum_h W_h S_h^2$$

To use this formula, it was assumed that the quarters of the field were four equal sized strata with a random sample of two in each. The formula simplifies to

$$V(\hat{\bar{y}}_{st}) = \frac{1}{32} \sum_{h=1}^{4} \sum_{i=1}^{2} (y_{hi}-\bar{y}_h)^2$$

where: $h = 1, 2, \ldots, 4$ equal sized strata

$i = 1, 2$ units per strata

When only 2 units are present in the field, the formula reduces to the equivalent of a simple random sample variance with two observations.

3. Calculated means and variances.

Table A1 in the Appendix contains field level estimates using 8 units per field, if available, for the 72 soybean fields having harvest loss measurements.

In Table A1, the variables are defined as follows:

N = Number of units in yield calculation

YLDPAC = Biological yield per acre

YLDVAR = $V(\hat{\bar{y}}_{st})$

CV = Coefficient of variation for YLDPAC

HARVLOSS = Harvest loss from a sample of two

ACHRV = Harvested acres in the field

FARMYLD = Farmer reported yield adjusted to 12.5% moisture

NYLDPAC = YLDPAC-HARVLOSS

It can be seen in the table that most of the CV's are less than 10 percent when 8 units are available. The objective yield compares well with the farmer yield in most cases particularly considering that the harvest loss estimate is not very precise at the field level. Table A2 shows a list of statistics calculated at the state level for the 72 soybean fields with harvest loss measurements. The net objective yield is not significantly different from the average farmer yield.

A brief explanation of the procedure for calculating between and within components of the biological yield variance follows. Fields are selected with probability proportional to size as determined in the June Enumerative Survey. If we assume that the probability of selection was determined using actual size rather than an estimate of size and that the ratio of sampled units to total units within each field is small enough to be ignored, then an unbiased estimate of the ~~total~~ variance is (Cochran pg. 308)

$$\hat{V}(\bar{\bar{y}}) = \frac{\sum_{i=1}^{n} (\bar{y}_i - \bar{\bar{y}})^2}{n(n-1)} \qquad i = 1, 2, \ldots, n \text{ fields}$$

where: $\bar{y}_i$ = field level mean yield

$$\bar{\bar{y}} = \frac{\sum_{i=1}^{n} \bar{y}_i}{n}$$

It has been shown in some unpublished notes by Tortora that an unbiased estimate of the within field variance component is

$$\hat{V}(\bar{\bar{y}})_w = \frac{\sum_{i=1}^{n} V(\hat{\bar{y}}_{st_i})}{n^2} \qquad i = 1, 2, \ldots, n \text{ fields}$$

The between component can be obtained by subtraction.

The variance of the net state level yield (72 observations) was calculated by adding the harvest loss variance to the variance of the state biological yield and subtracting a covariance term.

Tables A3 and A4 are similar to Tables A1 and A2 except they pertain only to the regular objective yield samples. Expectedly, the correspondence between net yield and farmer yield is generally not as good at the field level. However, at the state level the net yield is close to the farmer yield and less than a bushel away from the net yield with 8 units per field.

The following table shows state level means and variances using all fields with farmer reported yield. The state average harvest loss was subtracted to obtain net yield.

Table 1

	Obs.	Mean	Var	CV
Net Yield (8 units)	126	38.13	.77	2.3%
Net Yield (2 units)	126	37.63	1.28	3.0%
Farmer Yield	126	38.04	.73	2.2%

C. Assumptions Used in Estimating Means and Variances in Regular Objective Yield Program.

1. Row widths within a sample are equal.

The method used in Section I.B.1. did not make this assumption but it is made in the regular program when the estimated number of pods per unit area from Form C is calculated and when the variance of the estimate is calculated (see Section I.A.1.b.). While it is agreed that the mean width of one row does not vary a great deal within a field, if the row width is positively correlated with number of pods, the regular objective yield estimate will be consistently high. The corresponding variance estimate will also be overstated. Since the row width is on the G.E. strung record at the unit level, it would be better not to assume the row widths are equal.

2. Mean weight per pod is the same for both units within a sample.

There are really two different assumptions concerning weight per pod. The mean weight of each whole pod is assumed to be equal between units when X_2 is calculated in Section I.A.1.b.

The mean threshed weight of each pod is assumed to be equal between units when the weight per pod from Form C is derived (see Section I.A.2).

In the first case, since there is generally a negative correlation between wt/pod and number of pods, the estimate of pods per unit area will be low when the number of pods in the unit not counted is higher than the number of pods in the unit that was counted. The estimate will be high if the number not counted is less than the number counted. Since there is no reason to believe that unit 1 (which is normally counted) consistently has a higher or lower number of pods than unit 2, the estimate over many fields would not be effected by the assumption. Similarly, the variance of the estimated number of pods per unit area at the sample level is equally likely to be high or low.

In the second case where the threshed weight per pod is assumed to be equal between units, the estimate of weight per pod from Form C is also equally likely to be high as low at the sample level. The bad thing about the assumption, however, is that a within sample variance cannot be computed for the weight per pod component. The importance of this will be discussed in a later section.

3. Product of two components in Section I.A. is a single random variable.

There are at least four variables present in the two components on yield in Section I.A. They are row width, number of plants, number of pods and weight of pods. These variables are put together in a combination of products and ratios. Since 6-inch counts were not made in the additional research samples, it was not possible to examine the interrelationships between variables as they are combined in the regular program. However, the three component model used in forecasting was examined at some length because it is similar. This model as it appears on Page 15D-8 of the S&E Manual is as follows:

$$\text{Gross Yield per acre} = \left(\begin{array}{c}\text{No. of plants}\\ \text{per 18 sq. ft.}\end{array}\right)\left(\begin{array}{c}\text{No. of pods}\\ \text{per plant}\end{array}\right)\left(\begin{array}{c}\text{Weight}\\ \text{per pod}\end{array}\right)\left(\begin{array}{c}\text{Conversion}\\ \text{Factor}\end{array}\right)$$

The first component is a ratio of the two variables plant count and row width. The second component is a ratio of pod count and plant count and the third component contains pod weight and pod count. The problem with this method is that if there is a nonzero covariance between the two variables comprising each component, it is not theoretically correct to treat each component as a single variable. The reason is that in obtaining the mean for each component, the covariance is a factor in both the expectation and the variance. This can be taken care of by either calculating each of the components and the gross yield per acre at the unit level or if sample level means are used, including appropriate covariance terms in the mean and variance calculations.

To see if the covariance terms had any real impact on the field level means and variances, the components were each calculated assuming that they were composed of two random variables. The components were obtained by taking the ratios of field level means using 8 units per field. This procedure was compared with calculating the components at the unit level and aggregating to the field level. It was found that the first component could be treated as a single variable since the row width had such a small variance that the covariance term between number of plants and row width was negligible. However, the other two components generally had large enough covariance terms to warrant treating each component as the ratio of two variables. Number of pods and number of plants generally had a positive covariance while weight of pods and number of pods always had a positive covariance. An approximate formula for the variance of the ratio of two random variables follows:

$$\operatorname{Var}\left(\frac{X}{Y}\right) \doteq \frac{\operatorname{Var}(X)}{\mu_Y^2} + \frac{\mu_X^2 \operatorname{Var}(Y)}{\mu_Y^4} - \frac{2\mu_X \operatorname{Cov}(X,Y)}{\mu_Y^3}$$

This formula was applied within a stratified design and contrasted with treating the ratio as a single variable in a stratified design. Even though the covariances were positive, the two variable field level variances were usually higher than the one variable variances. The apparent reason is that the variance of each variable contributed enough to more than offset the covariance term. The variance of the third component could not be adequately evaluated because the pod count was only done in one unit per sample. To correctly calculate the variance, a pod count for each unit would be needed.

An approximate formula for the expected value of the ratio of two random variables is

$$E\left(\frac{X}{Y}\right) \doteq \frac{\mu_X}{\mu_Y} + \frac{\mu_X \operatorname{Var}(Y)}{\mu_Y^3} - \frac{\operatorname{Cov}(X,Y)}{\mu_Y^2}$$

$$= \frac{\mu_X}{\mu_Y} + \frac{\sqrt{\operatorname{Var}(Y)}}{\mu_Y^2} \left[\frac{\mu_X \sqrt{\operatorname{Var}(Y)}}{\mu_Y} - \rho \sqrt{\operatorname{Var}(X)} \right]$$

If a component is calculated by simply dividing the two field level means, the other terms are neglected. For the neglected terms to offset one another and vanish ρ must be equal to CV_Y/CV_X. So, the neglected terms will be positive if the coefficient of variation of the denominator is larger than the numerator or if the CV's are about the same and ρ is small. Similarly, a negative result will occur if CV_Y/CV_X is less than ρ. The effect of omitting the last two terms in the above formula could be fairly large at the field level. Calculations were not made to determine if the bias over many fields was large.

To simplify consideration of the problem of taking the product of three components which are themselves composed of two variables, it was assumed that each component was a single variable. Therefore, the problem reduces to calculating the mean gross yield and associated variance by taking the product of three variables. Approximate formulas for the mean and variance are as follows:

$$E(XYZ) \doteq \mu_x\mu_y\mu_z + \mu_z Cov(X,Y) + \mu_y Cov(X,Z) + \mu_x Cov(Y,Z)$$

$$Var(XYZ) \doteq \mu_y^2 \mu_z^2 \sigma_x^2 + \mu_x^2 \mu_z^2 \sigma_y^2 + \mu_x^2 \mu_y^2 \sigma_z^2$$

$$+ 2\mu_x\mu_y\mu_z^2 Cov(X,Y) + 2\mu_x\mu_y^2\mu_z Cov(X,Z) + 2\mu_x^2\mu_y\mu_z Cov(Y,Z)$$

These formulas were used at the field level.

The effect of calculating E(XYZ) as the product of the three components at the field level and omitting the covariance terms is a 3.1 bushel/acre overestimate of the state mean gross yield (72 fields, 8 units per field). Using just the 2 regular objective yield units, the biased estimate is 1.4 bushel/acre higher. The state level variance of the biased estimate is about 50 percent higher with 8 units per field and 15 percent higher with 2 units per field. The corresponding CV's are .4 percent higher with 8 units per field and .1 percent higher with 2 units per field.

This discussion is intended to simply point out that when yield components are used, yield estimates obtained by omitting the covariance terms are biased upward and variance estimates are higher. The actual impact of treating multiple yield components as if they were a single random variable needs to be looked at more closely. This same problem was analyzed more fully for corn and is in a later section.

II. CORN

A. How Final Corn Objective Yield Estimate is Computed.

$$\begin{pmatrix}\text{Gross yield per unit}\\ \text{area at 15.5\% moisture}\end{pmatrix} = \begin{pmatrix}\text{No. of ears}\\ \text{per unit area}\end{pmatrix}\begin{pmatrix}\text{Grain weight per ear}\\ \text{at 15.5\% moisture}\end{pmatrix}$$

1. Computation of number of ears per unit area.

   Calculated at <u>sample</u> level.

$$\begin{pmatrix}\text{No. of ears}\\ \text{per unit area}\end{pmatrix} = \frac{\begin{pmatrix}\text{Sum of ears in row 1}\\ \text{and row 2 of both units}\end{pmatrix}(\text{2 rows})}{(\text{width of 8 row spaces})(\text{15 feet})}$$

2. Computation of grain weight per ear at 15.5% moisture.

   Calculated at <u>sample</u> level.

$$\begin{pmatrix}\text{Grain weight per ear}\\ \text{at 15.5\% moisture}\end{pmatrix} = \frac{\begin{pmatrix}\text{Field weight}\\ \text{per ear}\end{pmatrix}\begin{pmatrix}\text{Shelling}\\ \text{Fraction}\end{pmatrix}\begin{pmatrix}\text{Dry matter}\\ \text{Fraction}\end{pmatrix}}{(.845)}$$

where:

$$\begin{pmatrix}\text{Field weight}\\ \text{per ear (lbs.)}\end{pmatrix} = \frac{\begin{pmatrix}\text{Weight of ears from row 1}\\ \text{of units 1 and 2}\end{pmatrix}}{\begin{pmatrix}\text{Number of ears in row 1}\\ \text{of units 1 and 2}\end{pmatrix}}$$

$$\begin{pmatrix}\text{Shelling}\\ \text{Fraction}\end{pmatrix} = \frac{\begin{pmatrix}\text{Weight of shelled grain from ears}\\ \text{3 and 4 of row 1 of both units}\end{pmatrix}}{\begin{pmatrix}\text{Weight of ears 3 and 4 of row 1}\\ \text{of both units at time of shelling}\end{pmatrix}}$$

$$\begin{pmatrix}\text{Dry matter}\\ \text{Fraction}\end{pmatrix} = \frac{\begin{pmatrix}\text{Weight of grain at}\\ \text{time of moisture test}\end{pmatrix}(1 - \text{\% moisture})}{\left(\begin{pmatrix}\text{Weight of ears 3 and 4}\\ \text{in bag in both units}\end{pmatrix} - \begin{pmatrix}\text{Weight}\\ \text{of bag}\end{pmatrix}\right)\begin{pmatrix}\text{Shelling}\\ \text{Fraction}\end{pmatrix}}$$

To obtain biological (gross) yield per acre, the gross yield per unit area at 15.5% moisture is expanded to the acre level and expressed in bushels. As presented here, the units are (pounds/ foot^2) so (bushels/acre) would be obtained by multiplying by 43,560 and dividing by 56. Net yield is obtained by subtracting a harvest loss estimate based on two units in a quarter sample of all the objective yield fields. The formula for computing the harvest loss is on Page 15B-6 of the S&E Manual.

B. Comparison of Net Yield and Farmer Reported Yield.

1. Estimation of mean net yield at the field level.

It was felt that the net yield in the field could be best estimated by not using components. The variance of the field yield estimate is somewhat higher when two components are used because two variables have to be estimated instead of one and each has an associated error. To be able to properly estimate the within field variance, yield must be calculated on a unit basis rather than on the sample level. Since the field weight of ears and the shelled grain weight are combined for both units within a sample, a couple of assumptions must be made to estimate unit level yield. The first assumption is that the relative relationship between the weight of ears 3 and 4 and the total weight of ears harvested is the same within a unit. The second assumption is that the shelling fraction is the same for ears 3 and 4 of both units as it is for all ears harvested in both units. Using these assumptions, the biological field yield is computed as follows:

$$\text{YLDPAC} = \left(\frac{\sum_{i=1}^{4} \sum_{j=1}^{2} Y_{ij}}{8} \right) \left(\begin{matrix} \text{Adjustment} \\ \text{Factor} \end{matrix} \right)$$

where: i = 1, 2, ..., 4 samples

j = 1, 2 units

$$Y_{ij} = \frac{\left(\begin{matrix} \text{No. of} \\ \text{ears in} \\ \text{row 1} \end{matrix} \right)_{ij} \left(\begin{matrix} \text{Weight} \\ \text{of ears} \\ \text{3 \& 4} \end{matrix} \right)_{ij} \left(\begin{matrix} \text{Weight of ears} \\ \text{in row 1 of} \\ \text{both units} \end{matrix} \right)_{i} SF_i DMF_i}{\left(\sum_{j=1}^{2} \left(\begin{matrix} \text{No. of} \\ \text{ears in} \\ \text{row 1} \end{matrix} \right)_{ij} \left(\begin{matrix} \text{Weight} \\ \text{of ears} \\ \text{3 \& 4} \end{matrix} \right)_{ij} \right) \left(\begin{matrix} \text{Avg.} \\ \text{width} \\ \text{of 2} \\ \text{rows} \end{matrix} \right)_{ij} (15 \text{ ft.})(.845)}$$

where: $$\left(\begin{matrix} \text{Weight} \\ \text{of ears} \\ \text{3 \& 4} \end{matrix} \right)_{ij} = \frac{\left(\left(\begin{matrix} \text{Weight of ears} \\ \text{3 \& 4 in bag} \\ \text{in both units} \end{matrix} \right) - \left(\begin{matrix} \text{Weight} \\ \text{of} \\ \text{bag} \end{matrix} \right) \right)_{i} \left(\begin{matrix} \text{Weight} \\ \text{of ears} \\ \text{3 \& 4} \end{matrix} \right)_{ij}}{\sum_{j=1}^{2} \left(\begin{matrix} \text{Weight of} \\ \text{ears 3 \& 4} \end{matrix} \right)_{ij}}$$

SF_i = Shelling fraction in i^{th} sample

DMF_i = Dry matter fraction in i^{th} sample

Adjustment factor converts from (lbs./ft.^{2}) to (bushels/acre)

The sample level gross yield using the above method is different from that which would be obtained from the regular method in two ways. Average row width for individual units is used and the ear count is from row 1 of each unit rather than from both rows of each unit. The reason for not assuming row widths to be equal within sample was discussed in Section I.C.1. The reason for using only the number of ears from one row within a unit rather than from two rows is probably open to some debate. It is recognized that the 2-row ear count will provide a better estimate of the number of ears per unit area at a state level but, at the field level, the inclusion of ear counts for which there are not associated ear weights introduces room for additional error in the field yield estimate. Since we were primarily interested in estimating the field yield, it was not felt that 8 units per field was a sufficient number to permit double sampling to work to our advantage. If a larger number of units within field had been used, the 2-row ear counts would have been useful. The effect of using 2-row plant count is discussed in a later section.

It should also be pointed out that the assumption used to estimate field ear weight on a unit basis is probably not a good one but there was no alternative if the within field variance is to be calculated according to the sampling design. The assumption itself probably causes the estimated variance to be understated. Field weights should be made separately for each unit if a good estimate of variance is to be obtained.

2. Estimation of variance of mean biological field yield.

   The variance was estimated with the same method as presented in Section I.B.2.

3. Calculated means and variances.

   Table A5 in the Appendix contains field level estimates using 8 units per field, if available, for the 45 corn fields having harvest loss measurements. The variables are as previously defined in Section I.B.3. As was the case with the soybeans, most of the CV's are less than 10 percent. Table A6 shows some state level statistics for the same 45 fields. The net objective yield is not significantly different from the average farmer yield. However, the farmer yield has not been adjusted to the standard 15.5 percent moisture because moisture percentage is no longer asked on the post-harvest interview. If the farmer yield tends to be based on weight of grain immediately after harvest, the moisture percentage is likely to be over 20 percent and the difference between the objective yield and farmer yield would be greater than it appears to be. The other entries in Table A6 were calculated as explained in Section I.B.3.

Table A7 contains the same information as Table A6 except only the regular objective yield samples were used. The net yield is actually closer to the farmer yield than in the previous table. The between field and within field variance components were not calculated.

The following table shows state level means and variances using all fields with farmer reported yield. The state average harvest loss was subtracted to obtain net yield.

Table 2

	Obs.	Mean	Var	CV
Net Yield (8 units)	166	125.48	4.58	1.7%
Net Yield (2 units)	166	124.04	6.04	2.0%
Farmer Yield	166	121.13	3.27	1.5%

C. Assumptions Used in Estimating Means and Variances in Regular Objective Yield Program.

Several assumptions used in the estimation procedure have been mentioned and now some of them will be discussed more fully.

1. Row widths within a sample are equal.

This assumption was discussed for soybeans in Section I.C.1. and won't be dealt with in any great detail here. It is felt that it would be better not to make this assumption since row widths are obtained for individual units. While the row width usually is consistent within fields, a quick look at the data indicated that the 4-row measurement was unequal within sample about 3 times as often as it was equal. The differences were usually small but some were a foot or more.

2. Shelling fraction is the same for ears 3 and 4 of both units as it is for all ears harvested in both units.

This assumption cannot be addressed directly because shelling fractions are not available on a unit basis for ears 3 and 4 or for the field ears. Presumably ears 3 and 4 are an adequate subsample. Since we had at most four sample level shelling fractions within a field, it was possible to get an idea of the variability. On the average, the sample level shelling fraction could be expected to lie within 4.3 percent of the field mean shelling fraction 95 percent of the time. The data did not indicate a significant correlation between the shelling fraction and the weight per ear. As far as calculating a state level yield is concerned, this assumption appears to be reasonable. However, to calculate a within field variance, a unit level shelling fraction would be needed to go with unit level field weight per ear.

3. Mean gross sample level yield is equal to the product of two components.

   In Section II.A. the gross yield per unit area at 15.5 percent moisture is found to be equal to the product of the number of ears per unit area and the grain weight per ear at 15.5 percent moisture. Since the components are sample level means, there is a covariance term in the expectation. That is,

   $$E(XY) = \mu_x \mu_y + Cov(X,Y)$$

   The use of this expectation assumes that each component is a single random variable. As pointed out in Section I.C.3. this is really not the case since each component is a ratio of two random variables. For sake of discussion, however, it is assumed that each component is a single random variable.

   The question then becomes, what is the effect of omitting the covariance term? It is difficult to estimate the covariance directly because a rather large assumption needs to be made to estimate the weight per ear component on the unit level (discussed in Section II.B.1.). The covariance can be estimated indirectly by finding the difference between the yields obtained using components without a covariance term and not using components. At the field level using all 8 units, the covariance term generally accounted for a difference of one to two bushels per acre with a maximum of seven bushels per acre. At the state level, however, the effect of the covariance term was small (see Table 3). With 45 fields and 2 units per field, the mean yield obtained by omitting the covariance term was .5 bushels higher. With 191 fields and 2 units per field, the mean without a covariance term was 1.1 bushels higher. The two components were more often negatively correlated but the positive covariances tended to be larger so that offsetting biases made the effect of omitting the covariance small. Whether this can be expected to consistently happen is not known. It is suggested that components not be used on the final estimate and that either covariances be calculated during the forecasting when components are needed or components be multiplied on a unit level. Of course, to do either of the latter two suggestions, data would have to be available on a unit level.

4. Variance of state yield is calculated using the formula presented in Section I.B.3.

As presented in Section I.B.3., an unbiased estimate of the variance of the state level yield is

$$\hat{V}(\bar{\bar{y}}) = \frac{\sum_{i=1}^{n} (\bar{y}_i - \bar{\bar{y}})^2}{n(n-1)} \quad i = 1, 2, \ldots, n \text{ fields}$$

where: $\bar{y}_i$ = field level mean yield

$$\bar{\bar{y}} = \frac{\sum_{i=1}^{n} \bar{y}_i}{n}$$

Two assumptions needed to use this formula were presented. In addition, it is necessary for each $\bar{y}_i$ to be an unbiased estimate of the true field mean yield. Clearly, if the field level mean yield is estimated by taking the product of two component means, this is a biased estimate. Whether the same variance formula is appropriate is questionable. The theory needed to address this question was not considered in a rigorous manner. The intent here is just to show how the total variance changes when $\bar{y}_i$ is biased.

Table 3
45 fields, 8 units per field

	No components	Components (Cov included)	Components (Cov omitted)
YLDPAC	136.1	136.0	136.3
YLDPAC Variance	13.31	14.95	15.44
Between	10.40	11.59	---
Within	2.92	3.37	---
YLDPAC CV	2.7%	2.8%	2.9%

The first column of Table 3 does not agree with Table A6 because 2-row ear counts have been used. (The effect of the 2-row ear count is discussed in a later section). The mean biological yield per acre (YLDPAC) in the first two columns should be equal. The reason for this is that an exact formula (presented in Section II.C.3.) was used to compute the field level means. It is suggested that the covariance estimates are causing the differences. Since the field and state level yields should be the same in the first two columns, the total variance should also be the same. However, the within field variance is higher with components because two variables were estimated rather than one. The approximate variance formula which was used to obtain the variance of each field level mean yield is

$$Var(XY) \doteq \mu_Y^2 \; Var(X) + \mu_X^2 \; Var(Y) + 2\mu_X\mu_Y \; Cov(X,Y)$$

This formula was used within a stratified design and the within field variance component calculated as discussed in Section I.B.3. The third column in Table 3 shows the mean and total variance when biased field level means are used. The total variance of 15.44 is to be compared with 13.31 in the first column. From the total variance standpoint, it is again suggested that components not be used on the final estimate or, alternatively, that components be multiplied on the unit level so that covariance estimates can be bypassed.

D. Effect of Using 2-Row Ear Counts Versus 1-Row Ear Counts at Field and State Level.

It was stated in Section II.B.1. that 2-row ear counts were not used to estimate field level yields. It was felt that the variability of ear counts was such that with 8 units, more error would be introduced by including ear counts without associated ear weights than would be gained by using the additional information. Over many fields, however, the additional ear counts should be useful. In the same 45 fields used earlier, the mean yield was about 1 bushel per acre higher with the 2-row ear counts. With 191 fields, the difference was negligible (25 fields did not have farmer yield). So, 2-row ear counts made little difference when averaging over many fields. At the field level, however, differences of 3 or 4 bushels were common with some in excess of 10 bushels. At the sample level, differences as high as 20 bushels were observed. Since results are similar over many fields, it may be worthwhile to consider whether ears <u>need</u> to be counted in both rows.

III. CONCLUSIONS

A. Soybeans

1. Yield estimates made from objective yield type data generally compared favorably with the farmer reported yield at the field level with 8 units per field. The mean over many fields was less than 1 bushel/acre away from the farmer mean yield using either 8 units or 2 units per field. However, state yield estimates using the regular objective yield method were 3.5 bushel/acre higher than the farmer reported yield with 8 units and 1.1 bushel/acre higher with 2 units.

2. Use of components to obtain unbiased sample level yield requires either that covariances be calculated or that yield components be multiplied at the unit level. Both of these alternatives require unit level counts and measurements. Under the current objective yield methodology, covariances are needed to estimate the within field component of variance.

3. Row widths should be used on a unit level.

B. Corn

1. Yield estimates made from objective yield type data compared favorably with farmer yield but the farmer yield could not be adjusted to a standard moisture level. The yield estimates obtained using the objective yield method were essentially the same at the state level but some fairly sizeable differences occurred at the field level. The mean objective yield with 166 fields was about the same with either 8 units per field or 2 units per field.

2. Components are not needed to estimate yield at the end of the season. If they are used, either covariances need to be calculated or the product obtained at the unit level to produce unbiased yield estimates. Field ear weight should be obtained separately for each unit. The estimated variance of the biased state level objective yield estimate was somewhat higher than the variance of the corresponding unbiased estimate although the use of the same variance formula was questioned.

3. The need for 2-row ear counts was questioned.

4. Row widths should be used on a unit level.

Appendix

Table A1
Field Level Soybean Statistics
72 fields and 8 units per field

SAMPLE	N	YLDPAC	YLDVAR	CV	HARVLOSS	ACHRV	FARMYLD	NYLDPAC
2	8	38.7900	0.654	0.020846	6.1860	148.0	36.0000	32.6040
4	7	43.8088	2.250	0.034237	2.4636	120.0	40.2286	41.3451
6	8	43.3793	13.213	0.083796	13.3331	28.0	42.5280	30.0462
8	8	57.3673	87.721	0.163262	5.9916	40.0	50.0640	51.3757
10	8	46.9630	1.726	0.027975	4.0147	49.0	48.5486	42.9483
12	8	46.2519	10.768	0.070947	2.4752	48.0	42.7543	43.7767
14	8	47.8858	12.451	0.073689	3.9887	76.0	38.0000	43.8971
16	8	40.9241	8.174	0.069860	2.7080	129.7	36.8206	38.2162
18	8	40.2617	5.083	0.055996	4.8527	38.0	34.0000	35.4090
24	8	36.3276	2.445	0.043039	3.9930	56.0	30.1714	32.3346
26	8	7.5013	14.000	0.498794	2.9339	17.0	5.2697	4.5674
28	8	40.1671	51.192	0.178127	3.3204	54.0	35.7531	36.8467
30	8	41.7988	25.698	0.121280	1.7815	83.0	40.3200	40.0173
32	8	38.2495	2.008	0.037050	0.9282	60.0	35.1600	37.3214
34	8	36.0928	3.332	0.050575	1.6760	20.0	32.1829	34.4169
36	8	38.8654	61.924	0.202472	3.5504	35.0	43.2457	35.3150
38	8	52.1216	15.440	0.075389	2.0218	20.0	50.2423	50.0998
40	8	10.5161	2.517	0.150859	1.6376	10.0	11.1886	8.8785
42	8	46.8808	2.497	0.033709	2.0341	78.0	40.8000	44.8467
44	2	41.6350	103.263	0.244070	1.7018	76.8	51.4286	39.9333
46	8	42.0563	28.453	0.126834	2.7109	40.0	34.6000	39.3454
48	8	44.7932	7.931	0.062872	8.9838	62.0	40.6903	35.8094
50	8	40.1262	12.717	0.088872	6.3921	78.0	15.4286	33.7341
52	8	40.0534	37.257	0.152392	6.5942	100.0	40.8686	33.4592
54	8	45.9351	11.954	0.075269	2.9162	100.0	32.1829	43.0189
56	8	43.7070	11.187	0.076527	3.3519	13.0	23.4021	40.3552
60	8	52.2448	7.104	0.051016	5.4177	9.1	44.7429	46.8271
62	8	50.6466	67.908	0.162709	1.5960	9.5	38.8571	49.0506
64	8	56.3116	49.510	0.124954	7.1190	46.0	41.7600	49.1926
66	2	39.8310	415.610	0.511826	12.0393	8.0	36.0069	27.7917
68	8	26.2969	7.529	0.104342	4.0225	109.0	28.2645	22.2744
72	8	34.0142	6.386	0.074293	1.6582	25.0	37.0523	32.3560
76	8	35.9217	43.768	0.184171	6.5341	84.0	39.9000	29.3876
78	8	43.7070	17.664	0.096159	2.6234	61.0	49.6571	41.0836
80	8	53.5078	11.399	0.063097	5.5530	153.0	40.1143	47.9549
82	8	43.4194	6.888	0.060444	4.8991	25.0	27.0400	38.5203
84	8	34.3439	31.490	0.163394	4.3288	77.0	33.6000	30.0151
86	8	65.3116	51.771	0.110167	6.1215	124.0	50.2320	59.1902
88	8	50.3494	0.838	0.018180	2.0404	44.0	45.8229	48.3090
92	8	48.5291	60.228	0.159918	1.0661	52.0	47.5006	47.4630
94	8	58.4721	1.880	0.023447	3.8285	16.2	49.8286	54.6437
96	8	31.0285	11.341	0.108533	2.9013	33.0	42.2400	28.1271
100	8	50.4968	27.492	0.103833	1.5917	152.0	48.0429	48.9051
102	8	49.8719	2.925	0.034291	1.5766	31.0	38.7000	48.2953
104	8	47.5084	0.814	0.018989	2.5073	50.0	45.5143	45.0012
106	8	39.8521	50.907	0.179035	3.0350	65.0	46.7000	36.8171
108	8	42.5624	18.027	0.099755	3.3676	59.0	52.5000	39.1949
110	8	31.3835	18.422	0.136763	5.9634	480.0	38.1429	25.4201
112	8	27.8427	11.664	0.122663	2.8372	139.8	20.1143	25.0055
114	8	48.6301	2.997	0.035597	1.8475	43.9	45.2571	46.7826
116	8	44.1975	1.716	0.029642	0.8932	355.0	42.0960	43.3043
118	8	53.2425	0.888	0.017697	5.3070	60.0	44.7429	47.9356
120	8	49.4521	41.849	0.130815	1.0993	40.0	50.2857	48.3528
122	8	40.4053	6.771	0.064400	3.6925	35.0	33.6230	36.7128
124	8	45.3253	2.8024	0.036934	3.7125	62.0	32.3657	41.6129
126	8	52.0432	24.2281	0.094579	3.9502	36.0	46.8291	48.0930
132	8	27.6164	17.9123	0.153253	2.4295	60.0	31.3543	25.1869
134	8	48.6246	4.0287	0.041279	1.8747	60.0	42.7543	46.7499
142	8	30.6767	17.3323	0.135712	2.3552	168.0	31.5429	28.3216
144	8	31.4518	18.9588	0.138439	3.6840	4.5	26.8457	27.7679
146	8	28.8528	14.5562	0.132232	0.4242	27.0	20.3429	28.4286
148	8	43.6284	10.9133	0.075720	19.5847	120.0	8.2286	24.0437
150	8	36.1074	3.6383	0.052827	4.3005	38.0	27.1543	31.8069
152	8	14.4341	7.2221	0.186184	0.9565	8.0	15.3000	13.4776
154	8	27.2872	8.4022	0.106228	1.9526	90.0	31.9634	25.3346
156	8	28.1487	3.7180	0.068501	2.9980	27.0	37.2114	25.1507
158	8	45.8749	8.9291	0.065137	3.3656	16.0	39.7257	42.5092
160	8	44.5954	7.1128	0.059804	0.7293	36.5	43.9714	43.8661
164	8	38.2634	11.6767	0.089305	6.1652	33.0	30.9029	32.0981
166	2	40.1652	3.2781	0.045078	4.1191	18.2	47.7257	36.0460
168	8	53.6888	7.4409	0.050808	3.0179	39.2	39.2291	50.6709
170	8	48.4517	1.7113	0.027000	3.7936	58.0	37.5558	44.6581

N=72

Table A2
State Level Soybean Statistics
72 fields and 8 units per field

Means	
YLDPAC	41.49
HARVLOSS	3.85
NYLDPAC	37.63
FARMYLD	37.24
Variances	
YLDVAR	1.50
Between fields	1.17
Within fields	.33
NYLDVAR	1.51
HARVLOSS Variance	.13
FARMYLD Variance	1.50
Coefficients of Variation	
YLDPAC CV	2.9%
NYLDPAC CV	3.3%
HARVLOSS CV	9.2%
FARMYLD CV	3.3%
Correlation (Pearson)	
NYLDPAC and FARMYLD	.72

Table A3
Field Level Soybean Statistics
72 fields and 2 units per field

SAMPLE	N	YLDPAC	YLDVAR	CV	HARVLOSS	ACHRV	FARMYLD	MYLDPAC
2	2	26.7712	2.87	0.06326	6.1860	148.0	36.0000	20.5851
4	1	37.8432	0.00	0.00000	2.4636	120.0	40.2286	35.3795
6	2	31.0130	26.23	0.16515	13.3331	29.0	42.5280	17.6799
8	2	60.2877	1391.37	0.61872	5.9916	40.0	50.0640	54.2961
10	2	46.8152	21.76	0.09964	4.0147	49.0	48.5486	42.8005
12	2	48.0508	121.74	0.22962	2.4752	48.0	42.7543	45.5757
14	2	43.6758	46.39	0.15595	3.9887	76.0	38.0000	39.6871
16	2	47.8266	102.75	0.21194	2.7080	129.7	36.8206	45.1187
18	2	40.9911	9.22	0.07406	4.8527	38.0	34.0000	36.1384
24	2	31.7332	13.44	0.11552	3.9930	56.0	30.1714	27.7402
26	2	11.8677	117.53	0.91350	2.9339	17.0	5.2697	8.9338
28	2	24.3415	26.64	0.21205	3.3204	54.0	35.7531	21.0211
30	2	45.0758	37.75	0.13630	1.7815	83.0	40.3200	43.2942
32	2	31.6084	1.92	0.04380	0.9282	60.0	35.1600	30.6802
34	2	39.6986	1.13	0.02676	1.6760	20.0	32.1829	38.0227
36	2	39.7034	53.20	0.18370	3.5504	35.0	43.2457	36.1530
38	2	49.1399	1.27	0.02290	2.0218	20.0	50.2423	47.1182
40	2	2.3154	5.36	1.00000	1.6376	10.0	11.1886	0.6778
42	2	44.0752	1.55	0.02820	2.0341	78.0	40.8000	42.0411
44	2	41.6350	103.26	0.24407	1.7018	76.8	51.4286	39.9333
46	2	45.1542	9.40	0.06791	2.7109	40.0	34.6000	42.4433
48	2	50.9562	11.54	0.06668	8.9838	62.0	40.6903	41.9724
50	2	37.9526	139.15	0.31081	6.3921	78.0	15.4286	31.5604
52	2	38.9143	48.51	0.17898	6.5942	100.0	40.8686	32.3201
54	2	38.3780	0.18	0.01114	2.9162	100.0	32.1829	35.4618
56	2	33.3433	19.24	0.13154	3.3519	13.0	23.4021	29.9914
60	2	57.1366	5.85	0.04231	5.4177	9.1	44.7429	51.7188
62	2	39.6950	223.11	0.37629	1.5960	9.5	38.8571	38.0989
64	2	57.6419	218.83	0.25663	7.1190	46.0	41.7600	50.5229
66	2	39.8310	415.61	0.51183	12.0393	8.0	36.0069	27.7917
68	2	33.1078	40.41	0.19200	4.0225	109.0	28.2645	29.0854
72	2	38.6784	86.93	0.24105	1.6582	25.0	37.0523	37.0202
76	2	22.4445	503.75	1.00000	6.5341	84.0	39.9000	15.9104
78	2	37.2971	4.84	0.05900	2.6234	61.0	49.6571	34.6737
80	2	50.5404	21.46	0.09166	5.5530	153.0	40.1143	44.9874
82	2	46.6759	26.12	0.10948	4.8991	25.0	27.0400	41.7778
84	2	0.3744	0.14	1.00000	4.3288	77.0	33.6000	-3.9544
86	2	77.7803	575.14	0.30833	6.1215	124.0	50.2320	71.6588
88	2	47.1290	4.73	0.04617	2.0404	44.0	45.8229	45.0886
92	2	49.5228	633.78	0.50835	1.0661	52.0	47.5006	48.4567
94	2	60.9923	21.19	0.07547	3.8285	15.2	49.8296	57.1638
96	2	46.2435	1.88	0.02969	2.9013	33.0	42.2400	43.3422
100	2	56.6488	32.70	0.10094	1.5917	152.0	48.0429	55.0571
102	2	40.3602	26.49	0.12751	1.5766	31.0	38.7000	38.7836
104	2	51.5136	12.67	0.06909	2.5073	50.0	45.5143	49.0063
106	2	46.2342	213.84	0.31629	3.0350	65.0	46.7000	43.1992
108	2	44.9228	13.94	0.08311	3.3676	59.0	52.5000	41.5553
110	2	66.3556	11.48	0.05107	5.9634	480.0	38.1429	60.3922
112	2	36.4801	11.16	0.09159	2.8372	139.8	20.1143	33.6429
114	2	57.5193	26.39	0.08931	1.8475	43.9	45.2571	55.6717
116	2	48.0793	0.85	0.01918	0.8932	355.0	42.0960	47.1860
118	2	56.9674	7.99	0.04960	5.3070	60.0	44.7429	51.6605
120	2	54.1172	9.63	0.05735	1.0993	40.0	50.2857	53.0178
122	2	34.9268	23.49	0.13876	3.6925	35.0	33.6230	31.2343
124	2	36.6128	0.975	0.026973	3.7125	62.0	32.3657	32.9004
126	2	59.6765	106.747	0.173131	3.9502	36.0	46.8291	55.7263
132	2	36.4511	139.107	0.323566	2.4295	60.0	31.3543	34.0217
134	2	38.2903	4.721	0.056747	1.8747	60.0	42.7543	36.4156
142	2	17.4493	216.853	0.843924	2.3552	168.0	31.5429	15.0942
144	2	24.3210	166.562	0.530648	3.6840	4.5	26.8457	20.6370
146	2	26.8055	12.742	0.133169	0.4242	27.0	20.3429	26.3813
148	2	39.0733	122.515	0.283280	19.5847	120.0	8.2286	19.4885
150	2	39.4584	2.400	0.039262	4.3005	38.0	27.1543	35.1580
152	2	6.8056	0.448	0.098333	0.9565	8.0	15.3000	5.8490
154	2	14.4855	1.328	0.079554	1.9526	90.0	31.9634	12.5329
156	2	31.5425	0.053	0.007324	2.9980	27.0	37.2114	28.5445
158	2	47.7947	15.432	0.082193	3.3656	16.0	39.7257	44.6290
160	2	36.4427	36.466	0.165704	0.7293	36.5	43.9714	35.7134
164	2	49.5998	14.093	0.075686	6.1652	33.0	30.9029	43.4346
166	2	40.1652	3.278	0.045078	4.1191	18.2	47.7257	36.0460
168	2	46.8752	13.164	0.077400	3.0179	39.2	39.2291	43.8574
170	2	52.4147	16.533	0.077574	3.7936	58.0	37.5558	48.6211

N=72

Table A4
State Level Soybean Statistics
72 fields and 2 units per field

Means	
YLDPAC	40.73
HARVLOSS	3.85
NYLDPAC	36.88
FARMYLD	37.24
Variances	
YLDVAR	2.76
Between fields	1.53
Within fields	1.23
NYLDVAR	2.72
HARVLOSS Variance	.13
FARMYLD Variance	1.50
Coefficients of Variation	
YLDPAC CV	4.1%
NYLDPAC CV	4.5%
HARVLOSS CV	9.2%
FARMYLD CV	3.3%
Correlation (Pearson)	
NYLDPAC and FARMYLD	.65

Table A5
Field Level Corn Statistics
45 fields and 8 units per field

SAMPLE	N	YLDPAC	YLDVAR	CV	HARVLOSS	ACHRV	FARMYLD	NYLDPAC
4	8	156.798	273.263	0.105428	1.4495	152.0	154.605	155.347
8	8	109.564	26.057	0.046590	6.1720	44.0	100.864	103.392
12	8	102.126	264.995	0.159399	3.1031	92.0	120.000	99.022
16	8	148.314	30.392	0.037171	13.6250	36.0	126.000	134.689
20	8	124.661	42.161	0.052086	2.6022	12.7	102.362	122.059
24	8	162.048	86.471	0.057384	4.9463	101.5	147.783	157.102
28	8	125.127	102.271	0.080821	11.7189	36.0	133.000	113.408
36	8	136.740	85.621	0.067670	5.3754	190.0	142.000	131.365
40	8	161.054	124.826	0.069371	7.1056	20.0	130.000	153.949
44	8	117.521	180.380	0.114282	3.6929	70.0	120.000	113.828
48	8	152.118	234.677	0.100706	13.0952	59.5	155.042	139.023
52	8	121.106	95.372	0.080639	11.0158	69.0	133.333	110.090
56	8	152.040	62.189	0.051868	1.2591	58.9	129.711	150.781
60	8	143.876	143.983	0.083400	9.4940	55.0	131.000	134.382
64	8	134.790	70.776	0.062414	7.0658	44.1	150.000	127.724
68	8	153.900	188.934	0.089313	7.1028	27.0	120.370	146.797
76	8	130.517	342.712	0.141840	6.7745	56.0	105.000	123.742
80	8	121.272	121.880	0.091035	5.7314	19.0	130.000	115.540
84	8	159.398	23.625	0.030493	2.1751	85.0	129.412	157.223
88	8	168.623	60.591	0.046162	1.5394	40.0	180.000	167.083
92	8	149.211	54.595	0.049519	8.7632	55.1	139.909	140.448
96	8	111.674	322.853	0.160898	9.4116	38.4	112.005	102.262
100	8	154.147	121.870	0.071617	3.0729	61.0	134.016	151.074
108	8	146.754	102.077	0.068845	21.6617	195.0	147.179	125.093
116	8	46.954	16.005	0.085204	0.3468	34.0	35.000	46.607
120	8	141.220	161.086	0.089874	10.3846	77.0	125.000	130.835
144	8	183.831	121.612	0.059989	3.1678	53.5	120.000	180.663
148	8	152.117	214.610	0.096305	5.4575	66.0	130.000	146.659
152	8	115.910	485.728	0.190141	14.9323	37.0	110.000	100.978
160	8	118.187	66.859	0.069184	1.3113	32.0	110.000	116.876
164	8	169.871	95.783	0.057613	5.0408	21.0	133.333	164.831
176	8	133.629	244.776	0.117080	12.3332	54.5	124.771	121.296
180	8	134.723	472.999	0.161432	7.7322	50.0	110.000	126.990
184	8	149.927	60.981	0.052086	27.2511	56.6	120.671	122.676
188	8	135.277	25.534	0.037354	30.3581	70.0	114.286	104.919
192	8	128.237	60.439	0.060625	12.2727	310.0	125.000	115.964
200	8	130.770	87.901	0.071695	6.6145	50.0	127.000	124.155
204	8	67.945	178.171	0.196454	5.7265	90.0	97.500	62.219
212	8	115.136	83.921	0.079566	16.8698	36.0	120.000	98.266
216	8	138.799	60.804	0.056179	2.5764	25.0	120.000	136.223
220	8	110.372	39.745	0.057119	7.5603	55.0	130.000	102.812
224	8	121.052	546.897	0.193188	5.2313	46.5	100.968	115.821
228	8	143.576	4.813	0.015281	8.7338	39.0	104.590	134.843
232	8	146.818	450.542	0.144574	17.9399	19.5	135.026	128.878
240	8	157.896	4.874	0.013982	8.0900	64.0	127.000	149.806

N=45

Table A6
State Level Corn Statistics
45 fields and 8 units per field

Means	
YLDPAC	135.24
HARVLOSS	8.40
NYLDPAC	126.84
FARMYLD	124.31
Variances	
YLDVAR	14.02
Between fields	10.74
Within fields	3.28
NYLDVAR	14.52
HARVLOSS Variance	.95
FARMYLD Variance	10.09
Coefficients of Variation	
YLDPAC CV	2.8%
NYLDPAC CV	3.0%
HARVLOSS CV	11.6%
FARMYLD CV	2.6%
Correlation (Pearson)	
NYLDPAC and FARMYLD	.66

Table A7
State Level Corn Statistics
45 fields and 2 units per field

Means	
YLDPAC	132.23
HARVLOSS	8.40
NYLDPAC	123.83
FARMYLD	124.31
Variances	
YLDVAR	22.58
Between fields	-
Within fields	-
NYLDVAR	22.95
HARVLOSS Variance	.95
FARMYLD Variance	10.09
Coefficients of Variation	
YLDPAC CV	3.6%
NYLDPAC CV	3.9%
HARVLOSS CV	11.6%
FARMYLD CV	2.6%
Correlation (Pearson)	
NYLDPAC and FARMYLD	.52