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The Effect Of Row Width On Data And Models Used In The Soybean Objective Yield Survey

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ABSTRACT

The effect of row-width on soybean objective yield forecast models was determined to be negligible. Covariance analysis techniques were used to determine if row-width affects forecast model parameters. Yield components from narrow- and wide-row samples were examined. Narrow-row samples have more plants, smaller weight per pod, less pods per plant, and more pods per 18 sq. ft. than wide-row samples. Imputation of average values in early season forecasts should reflect the domain differences.

KEYWORDS

Covariance analysis, row width, forecast models, soybean objective yield

This paper was prepared for limited distribution to the research community outside the U. S. Department of Agriculture. The views expressed herein are not necessarily those of NASS or USDA.

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CONTENTS

SUMMARY

The purpose of this research was to investigate the effects of row-width on soybean objective yield forecasts to determine whether alternative models or procedures are necessary. The frequencies of wide-row, narrow-row and broadcast units were examined over an 8 year period. The data showed that four states - Illinois, Minnesota, Missouri and Ohio - had 10 percent or more soybean objective yield units classified as narrow-row. The state with the largest percentage of narrow-row units was Ohio, with 40 percent. In Louisiana 26 percent of the soybean units were classified as broadcast.

Models were constructed using data from 1977-84 with row-width type as a treatment. Results showed that separate forecast models for wide-row, narrow-row, and broadcast units are not necessary.

Yield components from the two row types were examined. Narrow-row samples have more plants, smaller weight per pod, fewer pods per plant and more pods per 18 sq. ft. than wide-row samples. These results indicate that average number of pods per plant and the average weight per pod components of yield imputed in early season forecasts should be computed separately for narrow-row and wide-row samples.

Finally, count unit size in narrow-row soybeans was examined. A comparison of 6-inch and 12-inch count units showed no difference in the number of plants per 18 sq. ft. Row-width does affect the number of plants in the 6-inch section. Narrow-row soybeans have fewer plants per 6-inch section because of seeding rates. Recommended changes in the imputation procedures could reduce the need for changes in the data collection procedures.

THE EFFECTS OF ROW WIDTH ON DATA AND MODELS USED IN THE SOYBEAN OBJECTIVE YIELD SURVEY

By Robert J. Battaglia[1]

INTRODUCTION

The National Agricultural Statistics Service (NASS) began research on the soybean objective yield survey in 1956. Nine of the fifteen states currently in the program were involved in the initial research. The survey became operational in 1967. At the time soybean objective yield procedures were developed, soybeans were customarily planted using a corn planter; row-widths averaged around 3 feet in all nine states [11, 12].[2] The survey developers recognized the potential for an insufficient number of plants in the 6-inch sections of narrow-row units. Detailed plant counts obtained from the 6-inch sections are used to forecast the number of pods with beans per plant at harvest. However, acreage of narrow-row soybeans was concentrated in Ohio and justification for development of an alternative procedure was not deemed sufficient at the time. Since then the acreage of narrow-row plantings has increased. Agronomic research shows that decreasing row width while increasing the space between plants in a row can increase yield [14,15]. The purpose of this study was to (1) investigate the effects of narrow-row soybeans on objective yield forecasts and (2) to determine whether alternative procedures are necessary.

The study had 4 objectives. First, determine which states had significant numbers of narrow-row units. Second, test the effect of row-width on the slope and intercept of forecast models. Third, compare differences in number of plants per unit, number of pods with beans per plant, and weight of beans per pod between wide- and narrow-row soybeans. Finally count unit size in narrow-row soybeans was examined.

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[2] Numbers in brackets refer to literature cited in the references at the end of the report.

ANALYSES

Frequencies of Row Width Types

The first step in this analysis was to determine which states had significant numbers of narrow-row units. Narrow-row soybeans were defined to possess row widths of less than 18 inches. Soybean objective yield data from 1977-84 were used to construct Table 1. This table shows frequencies and percentages of soybean units by row-width type for each OY state. Only four states (Illinois, Minnesota, Missouri, Ohio) show 10 percent or more of the sample units as narrow-row units. The state with the largest number of narrow-row units was Ohio with 40 percent.

Table 1: Percentage1/ of Soybean Objective Yield Units by row width category, October survey data, 1977-84

State2/	Units	Wide row3/	Narrow row	Broadcast
Illinois	673	83	14	3
Indiana	696	85	7	8
Iowa	805	96	3	1
Minnesota	553	85	10	5
Missouri (1)	756	83	13	4
Nebraska	463	98	1	1
Ohio	674	53	40	7
Alabama	817	93	2	5
Arkansas	1186	90	1	9
Georgia	813	98	1	1
Louisiana	849	73	1	26
Mississippi	1060	82	4	14
Missouri (2)	394	81	10	9
N. Carolina	793	88	7	5
S. Carolina	818	99	0	1
Tennessee	902	79	8	13

1/ Straight percentage average over the 8 years of survey data.
2/ Missouri Soybeans are divided into northern and southern districts. Northern soybeans are usually indeterminate varieties while southern soybeans are usually determinate varieties.
3/ Wide, width > 18 inches, narrow, width < 18 inches, broadcast, width = 18 inches (by definition).

Appendix 1 contains bar charts for these 4 states showing frequencies of row-width types by year. These charts reveal that the number of narrow-row units have increased sharply the past few years except in Ohio. The chart indicates that there has always been a higher percentage of narrow-row units in Ohio than in the other states.

Row Width Effect on Forecast Models

The next step was to compare a forecast model using row-width as an additional independent variable (full model) with the operational forecast model (reduced model) where the row-width type was ignored. The purpose of this analysis was to determine whether separate forecast models for narrow-row, wide-row and broadcast soybeans are necessary.

Methods

Soybean objective yield data (1977-84) from all fifteen OY states were used for this analysis. Outliers and leverage points were removed from the operational (reduced) models using Studentized T and Cook's D statistics [8]. This procedure removed similar data when applied to the full models. Residual plots of the forecast models were examined. The residual plots were near normal, with a slight negative skew for all states. These results make the alpha levels for any hypothesis tests approximate but still useable.

Two models were used to determine if separate forecast models are needed for each of the row-width types. As an example the models used in the analysis for October are described below. Model fit was compared using sums of squared errors (SSE) from models with separate and combined row-width types. Relative efficiency (RE) is defined as the ratio of the sum of squared errors from a covariance model based on separate row-type treatments vs a model where row-types were combined. Three row-width categories were used; narrow-row (less than 18"), wide-row (greater than 18") and broadcast (no rows, defined as row-width = 18").

An F statistic was not valid since the full and reduced models were built using the same data. Therefore the models were not independent. RE values less than one indicated there was a loss in model fit associated with combining row-width types. If the RE was close to one the row-width parameters in the full model did not account for much more of the variability of the dependent variable (Y's) than the reduced model [10].

Full model $Y_{ij} = U + A_j + (B_j)(Z_{ij}) + E_{ij}$ where

Y_{ij} = Final number of pods with beans i^{th} unit observation in j^{th} row-width type.
U = Overall mean
A_j = Treatment effect of j^{th} row-width type.
B_j = Regression coefficient of j^{th} row-width type.
Z_{ij} = October number of pods with beans.
E_{ij} = Error term

Reduced model $Y_{ij} = (U + A) + B(Z_{ij}) + E_{ij}$ where

A and B are constant for all row-width types.

Model diagnostics for the October full and reduced models are in Appendix 3.

Results

The RE's for the 15 states are listed in Table 2. The RE's for all states are near one. This indicates that separate forecast models for narrow-row, wide-row and broadcast units are not necessary at the state level.

Table 2: Relative efficiencies from combined row-type[1/] models vs. separate row-type models
Soybean Objective Yield, 1977-84

State[2/]	Relative Efficiency[3/] Aug & Sept Mat 3-5[4/]	Sept. Mat 6-9	Oct. Mat 7-9
Illinois	.947	.993	.996
Indiana	.961	.999	.985
Iowa	.977	.999	.999
Minnesota	.975	.997	.953
Missouri (1)	.917	.975	.990
Nebraska	1.000[5/]	.996	.973
Ohio	.901	.982	.985
Alabama	.998	.965	.989
Arkansas	.995	.995	.996
Georgia	.982	.980[5/]	.997
Louisiana	.951	.974	.981
Mississippi	.994	.961	.997
Missouri (2)	.942	.906[5/]	.984
N. Carolina	.993	.987[5/]	.956
S. Carolina	.990	.993[5/]	.999
Tennessee	.960	.983	.987

1/ Wide, width greater than 18 inches, narrow = width less than 18 inches, Broadcast = 18 inches (by definition).
2/ Missouri Soybeans are divided into northern and southern districts.
3/ Relative efficiency is defined as the ratio of the sum of squared errors from a covariance model with separate row-type treatments vs a model with a combined row-type. RE's < 1 represent a decrease in model fit by combining units with different row types.
4/ Forecast Models are developed by maturity category.
5/ RE was calculated using less than 250 observations.

Components of Yield

Methods

The purpose of this section is to evaluate components used to forecast and estimate soybean yield to see if they differ between narrow- and wide-row samples. Components of yield used in objective yield forecasts are; (1) number of plants per 18 sq. ft., (2) number of pods with beans per plant and (3) weight of beans per pod . Components used to estimate yield at harvest are; (1) number of pods with beans per 18 sq. ft. and (2) the weight of beans per pod.

Results

Table 3 contains the mean values of these components for narrow- and wide-row samples . These means were computed using 5 years of objective yield data (1980-84). The states were selected because at least 10 percent of the soybean samples were defined as narrow-row insuring adequate data to compute robust means for narrow-row units. Formulas used to compute values in Table 3 can be found in Section 15 of the OY S&E manual [13].

Table 3: Mean values of variables used to forecast and estimate yield from narrow- and wide-row samples Soybean Objective Yield, December data, 1980-84

Variable 2/	Row Type 3/	Illinois 1/ Mean	SE	Minnesota Mean	SE	Missouri Mean	SE	Ohio Mean	SE
Plants/	N	63.3	1.9	66.6	2.5	61.0	2.1	62.5	1.7
18 sqft	W	46.7	0.6	50.9	0.7	43.1	0.7	46.3	0.9
Pod Wt	N	.332	.007	.311	.007	.323	.007	.373	.005
Grams	W	.358	.003	.334	.003	.340	.004	.382	.004
Pods w/	N	24.9	1.3	23.2	1.3	22.2	1.4	22.3	0.8
Beans 4/	W	28.1	0.5	27.0	0.5	26.0	0.6	25.2	0.7
Pods/	N	1421	57	1423	67	1186	53	1266	35
18 sqft	W	1225	17	1294	18	1001	19	1060	20
Gross	N	41.8	1.9	38.7	1.8	35.3	1.9	41.6	1.2
Yld bu.	W	38.4	0.5	37.8	0.5	29.9	0.6	36.1	0.8
Samples	N	141		88		146		228	
	W	655		386		520		312	

1/ These states have > 10% narrow-row soybean yield samples.
2/ Formulas for these variables can be found in section 15 of the OY S&E manual [13].
3/ N=narrow-row, W=wide-row.
4/ Number of pods with beans per plant.

The first variable examined in Table 3 is the number of plants per 18 sq. ft.. These are the plant counts from the 42-inch rows expanded to 18 sq. ft. using the sample row-width. Differences in plant numbers between narrow- and wide-row samples were consistent across all four states. Narrow-row samples averaged about 17 additional plants. The second variable in the table is weight of beans per pod (labeled pod wt. grams). This value is determined in the lab from pods harvested in the 3-foot section and is used in both forecast and estimation procedures. Weight of beans per pod was lower in the narrow-row samples for all states although the difference in Ohio was negligible. Currently, a state average weight per pod is used in the operational forecast procedure. This procedure can cause an upward bias in narrow-row yield forecasts except in Ohio where the weight per pod between narrow- and wide-row samples is not different.

Counts of number of pods with beans per plant are made on plants in the 6-inch sections. The table shows wide-row soybeans average more pods per plant than the narrow-row beans. If there are no plants in a 6-inch section a state average number of pods with beans per plant is substituted into the forecast equation for that unit. For narrow-row units this substitution also causes an upward bias in forecasted yield since the average number of pods with beans for narrow-row units will be less than the state average. Appendix 2 and Table 4 show examples of how yield forecasts are affected when state average pod weight and number of pods per plant are used in forecast models.

The number of pods with beans per 18 sq. ft. is computed using lab counts of pods harvested from the 3-foot sections at maturity and expanded to 18 sq. ft. using the sample row-widths. The data show that narrow-row samples average more pods per 18 sq. ft. in all states and the difference is due to plant numbers rather than pods per plant. The last two items presented in Table 3 are the average gross yield per acre and the total number of samples with positive lab data from the 5 year period. Yield is computed as the product of; the number of pods per 18 sq. ft., weight per pod and a conversion factor that converts grams per 18 sq. ft. to bushels per acre. Average yields for the narrow-row samples were higher with differences ranging from 0.9 bushels per acre in Minnesota to 5.5 bushels in Ohio.

In summary, samples located in narrow-row fields will have more plants, smaller weight per pod, less pods per plant, and more pods per 18 sq. ft.. Gross yield for narrow-row samples was higher than average yields for wide-row samples. Differences in yield ranged from 0.9 bushels in Minnesota to 5.5 bushels in Ohio.

Table 4: The effect of using "state averages" in yield forecasts for narrow-row soybean objective yield units, Illinois data

Estimator 1/	Yield forecast components Plants/ 18 sqft.	Pods/ plant	Bean wt. per pod	Yield bu/acre
Narrow-row 2/	64	23.5	.332	44.4
Operational 3/	64	23.5	.353	47.2
Maturity=0 4/	64	26.1	.353	52.4

1/ Estimators are defined and calculations shown in Appendix 2.

2/ Pods per plant and bean weight per pod (5 yr. avg.) were calculated using narrow-row data only.

3/ Bean weight per pod is a 5 year state average computed over all units.

4/ No plants were present in the 6-inch count unit so state average pods per plant is used in addition to state average weight per pod.

Table 4 shows the results of how narrow-row yield forecasts are affected by substituting state average pod weight and state average number of pods per plant into the equations. Illinois data from Table 3 were used in this example. Computations of final pods per plant, state average pods per plant, and state average weight per pod are shown in Appendix 2. The narrow-row estimator was considered to be "true" since the components of yield were determined using only narrow-row data. The operational estimator uses weight per pod averaged over all samples. This resulted in a 2.8 bushel increase in yield when compared to the narrow-row estimate. If there were no plants in the 6-inch count section a unit is classified as maturity category zero. In this case, state average number of pods per plant is substituted into the forecast equation. This substitution resulted in a 5.2 bushel increase over the operational estimate and an 8.0 bushel increase over the "true" estimate. The state average substitutions also cause a downward bias in wide-row forecasts. The magnitude of the biases will be affected by the number of wide-row and narrow-row units and the differences in number of pods per plant and weight per pod between the two row-width types (see Table 3).

Count Unit Size in Narrow-row Soybeans

Methods

In the final part of the analysis the effect on yield components of expanding the 6-inch count unit to a 12 inch count unit was examined. The data used were from a study conducted in Ohio during 1983 [2]. In each sample field a research soybean unit was laid out in addition to the two operational units. The research unit was identical to the operational unit with the exception of a 12-inch count unit. In this research unit plant and plant component counts were obtained from both a 6- and 12-inch section. A yield per acre is forecast using three yield components. The first two components, number of plants per 18 square feet and number of pods with beans per plant, are used in monthly regression models to forecast final yield. The third component, weight of beans per pod, is derived using a five year historic average weight [12]. If there were no plants in the 6-inch section, state averages were used in the number of pods with beans regression models to forecast yield.

Results

Comparisons of yield forecast components were made to determine whether a 12-inch count unit would be more effective in narrow-row soybeans. The first yield component tested was the number of plants per 18 square feet. Plant numbers were calculated using counts from the 3-foot plus 6-inch sections and compared to those calculated from the 3-foot plus 12-inch section. A univariate paired T test showed no significant differences in plant numbers (T=1.14, Pr>|T|=.26, n=45). This was expected since most of the plants used to estimate plants per 18 square feet are counted in the 3-foot sections.

The number of plants in the 6-inch count unit was examined next. The 1983 study conducted in Ohio reported that extension service seeding rate recommendations were 2.4 seeds per foot of row for 7" rows and 6.1 seeds per foot in 20" rows [5]. This information is provided to show the differences in within row plant spacing between the two row types. Table 5 shows the probabilities of plants being included in one row of a 6-inch count unit in Ohio. Plants in the 6-inch count unit were numbered based on their position relative to the 3-foot section. For wide-row units the probability of a 4^{th} plant being included in a 6-inch section was .62. For narrow-row units 1 plant had a .68 probability. This indicates that 32 percent of the narrow-row units contained no plants.

Table 5: Probability of plants included in the first 6-inch section Ohio data, September 1983, soybean objective yield

No. plants in 6-inch section 1/	Wide-row probability	Narrow-row probability
1	.98	.68
2	.90	.39
3	.77	.21
4	.62	.13

1/ Plant 1 is the plant closest to the 3-foot section with Plant 2 being the second plant from the 3-foot section.

The component of yield most affected by narrow-row widths was the number of pods with beans per plant. This component is presently forecast using plant component counts from the 6-inch section. In narrow-row soybeans, plants are spaced farther apart within the row resulting in many units with no plants in the 6-inch sections. Number of plants per 18 square feet component was less affected by the plant spacing in narrow-row units since the plant counts are estimated by adding plants from the 3-foot section to the plants in the 6-inch count unit.

A consequence of increasing count unit size would be a potential increase in counting errors and other nonsampling errors due to enumerator fatigue, difficult working conditions etc.

RECOMMENDATIONS

An analysis of the frequencies of row-width types, by state, showed that four States (Ohio, Illinois, Missouri, and Minnesota) had 10 percent or greater narrow-row soybean units. Of those four states Ohio had the largest percentage, by far, at 40-percent. Louisiana had the most broadcast units (26 percent). Analysis on number of pods with beans forecast models using row-type as a treatment showed that separate models for wide, narrow and broadcast units were not necessary. An analysis of yield components showed that narrow-row samples have more plants, smaller bean weight per pod, fewer pods per plant, more pods per 18 sq. ft. and higher yields. The overall analysis indicates that narrow-row soybeans cause an estimation problem because of few or no plants in the 6-inch section. This problem affects the summarization procedures resulting in imputations for missing yield components.

The following recommendations are based on these findings:

1. Separate forecast models for wide, narrow and broadcast soybeans are not necessary.

2. State average weight per pod imputed for the forecast equations should be computed separately for narrow-row and wide-row units.

3. State average number of pods per plant used in forecast equations when no plants are in the 6-inch section should be computed separately for narrow-row and wide-row units.

   Methods Staff should run parallel forecasts using the original operational procedure to measure the effect of recommendations 2 & 3 on the forecast procedures.

4. If states do not have enough narrow-row units to provide adequate averages it may be necessary to increase the length of the count unit for narrow-row units. It is preferable however, not to alter the current data collection procedures since previous research indicates counting errors are associated with larger plant numbers in the count units.

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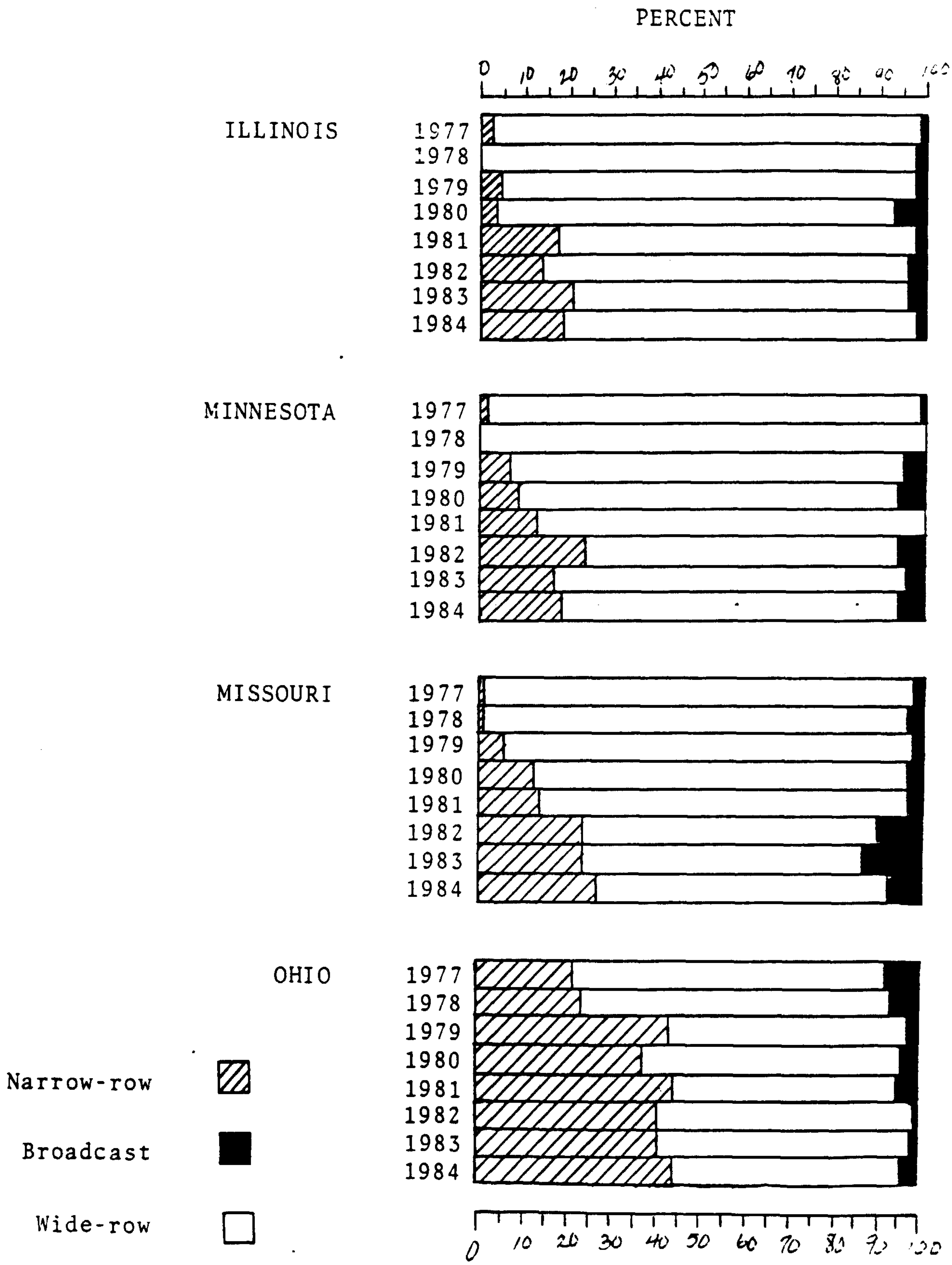
APPENDIX 1

PERCENTAGE OF ROW TYPES BY YEAR



Appendix 2: Forecasts using yield components from narrow-row units

INTRODUCTION

This appendix shows how soybean yield forecasts can change when yield component substitutions are used in the formulas. Information on the procedures and formulas can be found in section 15 of the S&E [13]. These substitutions are the result of operational procedures. Examples of yield forecast calculations are shown using Illinois data from Table 3. State average weight per pod is currently used in the yield forecast formula for all samples. It is a 5-year average over all units. State average pods per plant is computed over all units. This value is used as a substitute to forecast final pods when there are no plants in the 6-inch section. Again, Table 3 shows that the values for wide- and narrow-row units are different. The examples below show how yield forecasts are affected by these operational substitutions.

```
Yield = (#PLANTS/18sqft) (#PODS w BEANS/PLT) (WT/POD) (.088918)
         assume fixed        forecast         5 yr avg.
```

Example using Illinois data from Table 3:

State Avg. WT/POD = ((141*.332)+(655*.358))/796 = .353

State Avg. PODS/PLANT = ((141*24.9)+(655*28.1))/796 = 27.5

Illinois Oct. maturity 8 forecast model for PODS w BEANS/PLANT for an average narrow-row unit:

```
Final pods = -.653 + .972(24.9) = 23.5 PODS with BEANS/PLANT
substitute state avg. pods (27.5) = 26.1 "    "     "    "
```

Example 1. Use NARROW-ROW #PODS and NARROW-ROW WT/POD
    YLD=(64)*(23.5)*(.332)*(.088918) = 44.4 Bu/A

Example 2. Use NARROW-ROW #PODS and STATE AVG. WT/POD (OPERATIONAL)
    YLD=(64)*(23.5)*(.353)*(.088918) = 47.2 Bu/A

Example 3. Maturity=0 (no plants in 6" section) use STATE AVG. #PODS and STATE AVG. WT/POD (OPERATIONAL)

YLD=(64)*(26.1)*(.353)*(.088918) = 52.4 Bu/A

Example 4. Maturity=0 use STATE AVG. #PODS and NARROW-ROW WT/POD
YLD=(64)*(26.1)*(.332)*(.088918) = 49.3 Bu/A

Conclusion

The use of state average weight per pod and state average number of pods per plant in the operational procedures causes an upward bias in narrow-row soybean forecasts.

Appendix 3

Full Model Diagnostics

State	Overall Model Statistics DF	MSE[1]	Pr>F[2]	R^2	Significance Probability of Parameters: Oct. Pods Pr>F[3]	Row Type Pr>F[4]	Interaction Pr>F[5]
ILL	672	6	.0001	.97	.0001	.40	.36
IND	695	4	.0001	.98	.0001	.23	.58
IOWA	804	6	.0001	.98	.0001	.69	.65
MINN	552	3	.0001	.98	.0001	.10	.0002
MO-1	755	6	.0001	.98	.0001	.91	.32
NEB	462	4	.0001	.99	.0009	.01	.002
OHIO	673	7	.0001	.97	.0001	.99	.18
AL	816	11	.0001	.97	.0001	.61	.08
ARK	1455	37	.0001	.88	.0001	.17	.83
GA	812	12	.0001	.95	.0001	.83	.75
LA	848	21	.0001	.97	.0001	.68	.70
MISS	1059	30	.0001	.94	.0001	.50	.46
MO-2	393	21	.0001	.92	.0001	.15	.13
NC	802	17	.0001	.96	.0001	.17	.0001
SC	817	20	.0001	.94	.0001	.51	.68
TENN	901	17	.0001	.95	.0001	.36	.11

1/ Mean square error is an estimate of the variance of the true errors.
2/ Significance probability of MSR/MSE=F, indicates significance of some linear function of parameters different than 0.
3/ Significance probability that slope parameter is different than 0.
4/ Significance probability that intercepts of row-width treatments are equal.
5/ Significance probability that slopes of row-width treatments are equal.

Reduced Model Diagnostics

State	Overall Model Statistics				Significance Probability of Parameters	
	DF	MSE[1]	Pr>F[2]	R^2	Oct. Pods Pr>F[3]	Intercept Pr>F[4]
ILL	672	6	.0001	.97	.0001	.96
IND	695	4	.0001	.98	.005	.17
IOWA	804	6	.0001	.98	.005	.18
MINN	552	3	.0001	.98	.006	.18
MO-1	755	6	.0001	.98	.005	.17
NEB	462	4	.0001	.99	.005	.18
OHIO	673	7	.0001	.97	.007	.20
AL	816	11	.0001	.97	.0001	.80
ARK	1455	37	.0001	.88	.0001	.0001
GA	812	12	.0001	.95	.0001	.0004
LA	848	22	.0001	.96	.006	.27
MISS	1059	30	.0001	.94	.007	.29
MO-2	393	21	.0001	.92	.012	.43
NC	802	18	.0001	.95	.007	.27
SC	817	20	.0001	.94	.008	.29
TENN	901	17	.0001	.95	.007	.25

1/ Mean square error is an estimate of the variance of the true error.
2/ Significance probability of MSR/MSE=F, indicates if some linear function of parameters is significantly different than 0.
3/ Significance probability that the slope parameter is different than 0.
4/ Significance probability that the intercept parameter is different than 0.