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# AgRISTARS

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A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

## Yield Model Development

JANUARY 16, 1984

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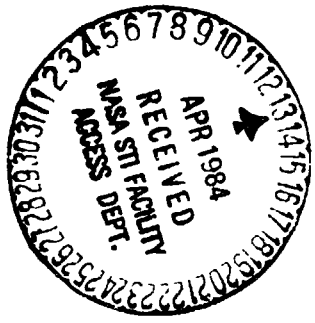
BRAZIL SOYBEAN YIELD COVARIANCE MODEL



SUSAN L. CALLIS
CLARENCE SAKAMOTO

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15. Supplementary Notes

16. Abstract

A model based on multiple regression was developed to estimate soybean yields for the seven soybean-growing states of Brazil. The meteorological data of these seven states were "pooled" and the years 1975 to 1980 were used to model since there was no technological trend in the yields during these years. Predictor variables were derived from monthly total precipitation and monthly average temperature.

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# BRAZIL SOYBEAN YIELD COVARIANCE MODEL

by

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and

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AISC Models Branch

January 16, 1984

## INTRODUCTION

The purpose of this study was to select weather variables that could be used to estimate the soybean yields for the country of Brazil. Soybean production in Brazil had its inception in the state of Rio Grande do Sul where soybeans were first planted in rotation with wheat. Presently, soybeans are planted in seven southern states: Rio Grande do Sul, Santa Catarina, Parana, Sao Paulo, Mato Grosso, Goias and Minas Gerais. This means that a variety of growing conditions are covered in this extensive area. Figure 1 is a map of the soybean-growing areas of Brazil.

The northern part of the soybean area, including the states of Mato Grosso, Goias, and Minas Gerais, are characterized by a "wet-and-dry" climate with a dry season of two or more months. The rest of the area is subtropical humid with relatively abundant rainfall which is well-distributed throughout the year but with slightly more rainfall in the warm months. Summers are hot and winters relatively mild. Temperatures in the summer are above 40°C in the plains of Rio Grande do Sul when warm air masses penetrate the plains. Southern Sao Paulo is the northern limit for frost occurrence.

The soybean growing season begins with planting in October and November and runs through April and May when harvest starts.

## METHOD

Multiple regression analysis of yield with selected agroclimatic indices was used tc derive a suitable model. The first approach taken was to develop a model for each state. However, lack of data for several states posed a problem and no suitable models were derived. Therefore, it was decided to create a covariance model whereby all the available data are combined to obtain a model for the country.

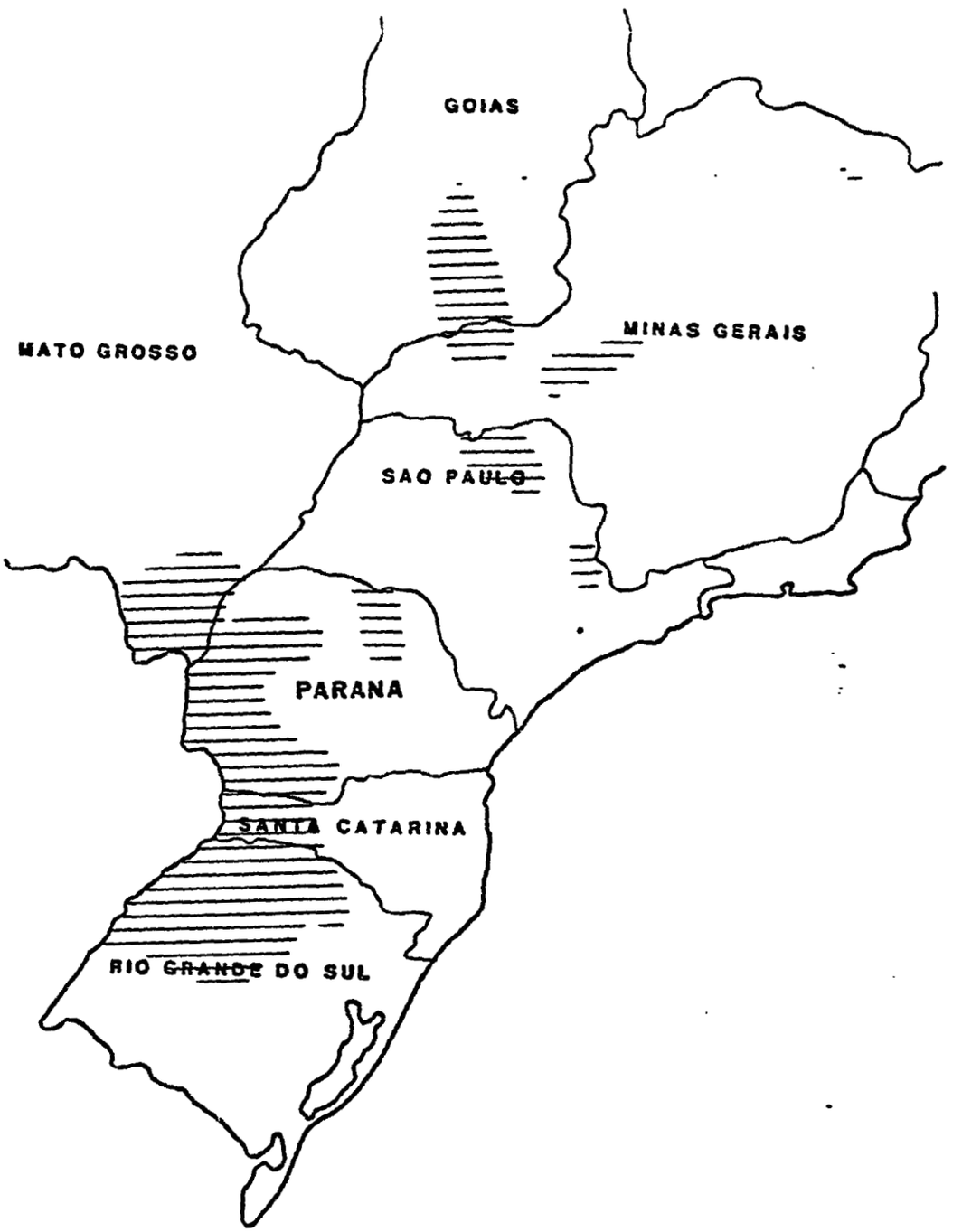


Figure 1. Soybean-growing areas of Brazil. (Pitcher, 1971)

Since moisture stress was considered a prime determinant of yield, the index P-PET (precipitation minus potential evapotranspiration) was used in the regressions.

The regression equation is:

$$\hat{Y} = \alpha + B_1 D + B_2 RDFN_i + B_3 (P\text{-}PET)_i + E$$

where

$\hat{Y}$ = Estimated yield,

$\alpha$ = Constant,

$B_j$ = Coefficients of the variables j = 1 - 3,

D = Dummy variable to adjust each state's yield to a base yield set by Rio Grande's do Sul's yield,

$RDFN_i$ = Deviation from normal of total precipitation for month i,

$P\text{-}PET_i$ = Precipitation minus PET for month i, and

E = Unexplained error

In developing the model, various procedures of the Statistical Analysis System (SAS Institute Inc., 1979) were used. The procedures used and the operations performed with each are summarized in the Appendix. The selected model had the highest $R^2$ and included variables significant at (or close to) the 10 per cent level and agronomically meaningful.

## DATA

The Brazil crop data for 1961 thru 1977 were obtained from the Foreign Agricultural Service (Sam Ruff, personal communication, 1982). The data were recorded with year of yield as year of harvest, so the weather influencing the crop occurred during year-1.

Meteorological data from 1975 through 1980 were used to model because there is no apparent trend in the yield data during this period. Table 1 lists


Figure 2. Location of Meteorological Stations Used to Derive Data Sets for the Brazil Soybean Model.

| STATE | METEOROLOGICAL STATION | WMO NUMBER |
|---|---|---|
| Goias | Brasilia/Cruzeiro | 83377 |
| | Goiania | 83423 |
| Mato Grosso | Ponta Pora | 83702 |
| | Pres Prudente | 83716 |
| | Foz do Iguacu | 83826 |
| Minas Gerais | Montes Claros | 83437 |
| | Araxa | 83579 |
| Parana | Londrina | 83766 |
| | Santa Branca | 83810 |
| | Foz do Iguacu | 83826 |
| | Porto Uniao | 83864 |
| Rio Grande do Sul | Ijui | 83805 |
| | Veranopolis | 83806 |
| | Farroupilha | 83807 |
| | Sao Borja | 83901 |
| | Passo Fundo | 83914 |
| | Julio de Castilhas | 83935 |
| | Santa Maria | 83936 |
| Santa Catarina | Porto Uniao | 83864 |
| | Sao Joaquim | 83920 |
| | Vacaria | 83918 |
| Sao Paulo | Pindorama | 83664 |
| | Ribeiro Preto | 83668 |
| | Mococa | 83680 |
| | Bauru | 83722 |
| | Jau | 83723 |
| | Limeira | 83728 |
| | Campinas | 83729 |
| | Monte Alegre do Sul | 83730 |
| | Tiete | 83777 |
| | Sao Paulo | 83800 |
| | Jundiqi | 83802 |

Table 1. Meteorological Stations Used to Derive Data Sets for the Brazil Soybean Model.

the stations used to derive the meteorological data set for each state. Figure 2 shows the location of each station. The seven states of Rio Grande do Sul, Santa Catarina, Parana, Sao Paulo, Mato Grosso, Goias, and Minas Gerais were included in the covariance model.

## PROCEDURES

The original variables used in the regression equation included "dummy variables" for six of the seven states (Rio Grande do Sul was the exceptio... The "dummy variables" adjust the contributions to yield of each of the states to a base yield which, in this case, is Rio Grande do Sul's yield. Weather variables selected reflected available moisture for the months December through March. The variables which were significant at the 10 per cent level were the "dummy variables" for Sao Paulo, Parana, and Santa Catarina and the P-PET for January and February (see the Appendix for a definition of P-PET). The coefficient for the Santa Catarina "dummy variable" was negative, indicating its yield was below that of the norm set by Rio Grande do Sul; the coefficients for the other dummy variables were positive. The coefficients for January and February P-PET were positive, indicating a need for moisture during those critical months. The statistics of the selected model are summarized in Table 2.

## TEST RESULTS

A jackknife test was run on the final model. In this test, a year was eliminated from the crop data and the model was used to predict that year's yield. This process was done for each successive year beginning with 1975. The test had to be run separately on each state. The results are printed on Tables 3 through 9 and plotted on Figures 3 through 9.

## APPENDIX

### Definition of Variables

P-PET, precipitation minus potential evapotranspiration, is an index used to measure the amount of moisture available for plant growth. Potential evapotranspiration is determined by the procedure developed by Thornthwaite (1948) which uses only temperature:

$$PET = \left(\frac{10T}{I}\right)^a$$

where I = Heat index, which is the sum of the 12 monthly indices i.

$$i = \left(\frac{T}{5}\right)^{1.514}$$

T = Monthly temperature in °C, and

a = An empirical exponent, $6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.79 \times 10^{-2} I + 0.49$.

The duration of daylight is used to adjust potential evapotranspiration as a portion of 12 hours.

### Statistical Analysis System Procedures Used

| | |
|---|---|
| PROC CORR | Computes correlation coefficients between variables, including Pearson product-moment and weighted product-moment correlation. |
| PROC PLOT | Graphs one variable against another, producing a printer plot. |
| PROC STEPWISE | Provides five methods for stepwise regression. Stepwise is useful when selecting variables to be included in a regression model from a collection of independent variables. |
| PROC STEPWISE FORWARD | Begins by finding the one-variable model that produces the highest $R^2$. For each of the other independent variables, FORWARD calculates F-statistics reflecting the contribution to the model if the variable were to be included. |
| PROC STEPWISE BACKWARD | Begins by calculating statistics for a model including all the independent variables. The variables are deleted from the model one by one until all the remaining variables produce F-statistics significant at the .10 level. |

| | |
|---|---|
| PROC STEPWISE STEPWISE | The stepwise method is a modification of the forward selection technique, differing in that variables already in the model do not necessarily stay there. After a variable is added (as in the forward selection method) the stepwise method looks at all the variables already included in the model and deletes any variable that does not produce an F-statistic significant at the .10 level. Only after this check is made and the necessary deletions accomplished can another variable be added to the model. |
| PROC STEPWISE MAXR | (Maximum $R^2$ improvement) Unlike the three techniques above, this method does not settle on a single method. Instead it looks for the "best" two-variable model, the "best" three variable model, and so forth. |
| PROC PETM | Uses latitude and mean monthly temperature to calculate Thornthwaite's potential evapotranspiration for each month. |
| PROC ZINDEX | Uses monthly PET's, precipitation, SS (beginning moisture in surface layer), AWCS (available water capacity in surface layer), SU (beginning moisture in the underlying layer), and AWCU (available water capacity in the underlying layer) to calculate Palmer's soil moisture budget, drought index Z, ET, and ET. |

S T A T I S T I C A L  A N A L Y S I S  S Y S T E M  14:37 TUESDAY, NOVEMBI

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE YIELD

ALL VARIABLES ENTERED  R SQUARE = 0.78015340  C(P) = 6.00000000

| | DF | SUM OF SQUARES | MEAN SQUARE | F | PROB>F |
|---|---|---|---|---|---|
| REGRESSION | 5 | 367.92708501 | 73.58541700 | 25.55 | 0.0001 |
| ERROR | 36 | 103.68156547 | 2.88004321 | | |
| TOTAL | 41 | 471.60864048 | | | |

| | B VALUE | STD ERROR | TYPE II SS | F | PROB>F |
|---|---|---|---|---|---|
| INTERCEPT | 14.01238649 | | | | |
| DUM4 (Sao Paulo) | 3.19206660 | 0.77780630 | 48.50650422 | 16.84 | 0.0002 |
| DUM5 (Parana) | 5.66181789 | 0.77538347 | 153.55986428 | 53.32 | 0.0001 |
| DUM6 (Santa Catarina) | -2.02308857 | 0.78146302 | 19.30242760 | 6.70 | 0.0138 |
| DP_PET1 | 0.01724433 | 0.00304775 | 92.20057197 | 32.01 | 0.0001 |
| DP_PET2 | 0.01021039 | 0.00340283 | 25.93009625 | 9.00 | 0.0049 |

ABLES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.



Table 2. Statistics of Brazil Soybean Model

BRAZIL SOYBEAN JACKNIFE RESULTS--TEST OF MODEL 1975-1980
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

14:37 TUESDAY, NOVI

| BETA2 | BEGMDLYR | ENDMDLYR | YIELDYR | YIELD | OBSYIELD | RSQ | PDER | DFRES | MSRES | BETA1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.52783 | 1976 | 1980 | 1975 | 12.6281 | 13.60 | 0.761662 | 0.25262 | 29 | 3.23711 | 13.9006 |
| 3.44230 | 1975 | 1980 | 1976 | 10.7397 | 14.80 | 0.795559 | 0.49241 | 29 | 2.80618 | 13.6744 |
| 3.47177 | 1975 | 1980 | 1977 | 13.2269 | 13.60 | 0.778618 | 0.65619 | 29 | 3.03799 | 14.1556 |
| 2.67107 | 1975 | 1980 | 1978 | 15.4910 | 11.11 | 0.859119 | 0.14115 | 29 | 1.95932 | 14.3360 |
| 2.98822 | 1975 | 1980 | 1979 | 17.4906 | 18.50 | 0.772079 | 0.81110 | 29 | 2.94903 | 14.1454 |
| 3.16776 | 1975 | 1979 | 1980 | 19.8857 | 18.56 | 0.755441 | 1.44984 | 29 | 3.11795 | 13.8794 |

| BETA3 | BETA4 | BETA5 | BETA6 | CONRIB1 | CONRIB2 | CONRIB3 | CONRIB4 | CONRIB5 | CONRIB6 |
|---|---|---|---|---|---|---|---|---|---|
| 5.35628 | -2.1065 | 0.0171992 | 0.0110723 | 13.9006 | 0 | 0 | 0 | -1.2056 | -0.06685 |
| 5.63172 | -1.6158 | 0.0213146 | 0.0070771 | 13.6744 | 0 | 0 | 0 | -3.1190 | 0.18440 |
| 5.53279 | -2.3067 | 0.0186637 | 0.0068621 | 14.1556 | 0 | 0 | 0 | -0.1325 | -0.79626 |
| 6.09044 | -2.2149 | 0.0156629 | 0.0126482 | 14.3360 | 0 | 0 | 0 | 0.1044 | 1.05051 |
| 5.83360 | -1.7355 | 0.0142275 | 0.0111423 | 14.1454 | 0 | 0 | 0 | 3.1998 | 0.14547 |
| 5.61586 | -2.1980 | 0.0176922 | 0.0098263 | 13.8794 | 0 | 0 | 0 | 4.0012 | 2.00511 |



Table 3. Results of Jackknife Test for State of Goias Soybean Model.

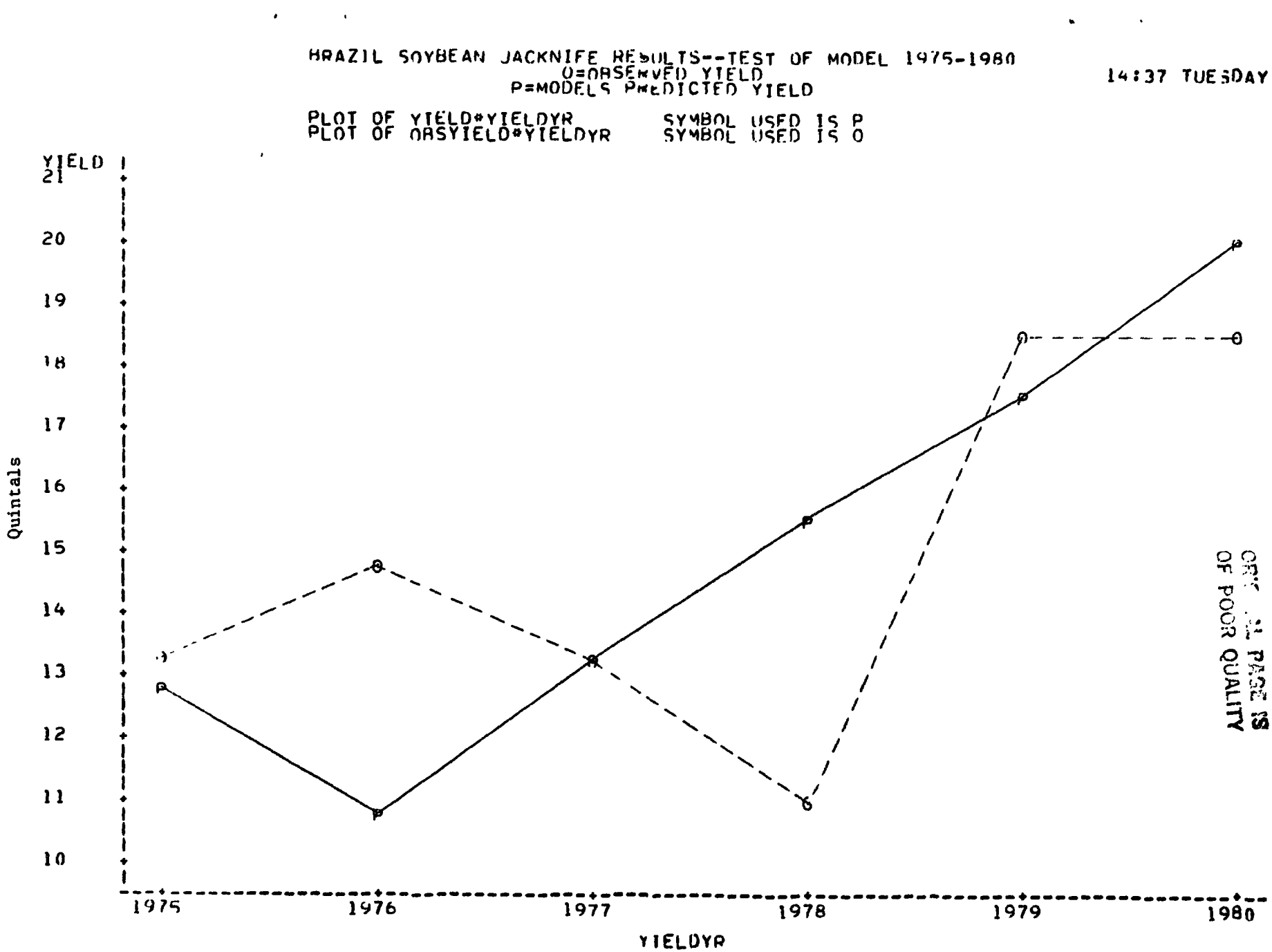


Figure 3. State of Goias Soybean Model.

S T A T I S T I C A L  A N A L Y S I S  S Y S T E M  14:37 TUESDAY, NOVEMBE

| BETA2 | BEGMDLYR | ENDMDLYR | YIELDYR | YIELD | OBSYIELD | RSQ | PDER | DFRES | MSRES | BETA1 |
|---|---|---|---|---|---|---|---|---|---|---|
| .52783 | 1976 | 1980 | 1975 | 13.1023 | 14.03 | 0.761662 | 0.208841 | 29 | 3.23711 | 13.9006 |
| .44230 | 1975 | 1980 | 1976 | 13.7371 | 15.40 | 0.795559 | 0.258191 | 29 | 2.80618 | 13.6744 |
| .47177 | 1975 | 1980 | 1977 | 16.0000 | 16.87 | 0.778618 | 0.756751 | 29 | 3.03799 | 14.1556 |
| .67107 | 1975 | 1980 | 1978 | 12.3155 | 12.12 | 0.859119 | 0.223157 | 29 | 1.95932 | 14.3360 |
| .98822 | 1975 | 1980 | 1979 | 13.9890 | 14.46 | 0.772079 | 0.149887 | 29 | 2.94903 | 14.1454 |
| .16776 | 1975 | 1979 | 1980 | 14.3398 | 16.34 | 0.755441 | 0.265288 | 29 | 3.11795 | 13.8794 |

| BETA3 | BETA4 | BETA5 | BETA6 | CONRIB1 | CONRIB2 | CONRIB3 | CONRIB4 | CONRIB5 | CONRIB |
|---|---|---|---|---|---|---|---|---|---|
| .35628 | -2.1065 | 0.0171992 | 0.0110723 | 13.9006 | 0 | 0 | 0 | -0.62259 | -0.175 |
| .63172 | -1.6158 | 0.0213146 | 0.0070771 | 13.6744 | 0 | 0 | 0 | -0.52136 | 0.584 |
| .53279 | -2.3067 | 0.0186637 | 0.0068621 | 14.1556 | 0 | 0 | 0 | 2.22888 | -0.384 |
| .09044 | -2.2149 | 0.0156629 | 0.0126482 | 14.3360 | 0 | 0 | 0 | -0.96383 | -1.056 |
| .83360 | -1.7355 | 0.0142275 | 0.0111423 | 14.1454 | 0 | 0 | 0 | -0.17727 | 0.020 |
| .61586 | -2.1980 | 0.0176922 | 0.0098263 | 13.8794 | 0 | 0 | 0 | -0.40595 | 0.866 |



Table 4. Results of Jackknife Test for State of Mato Grosso Soybean Model.

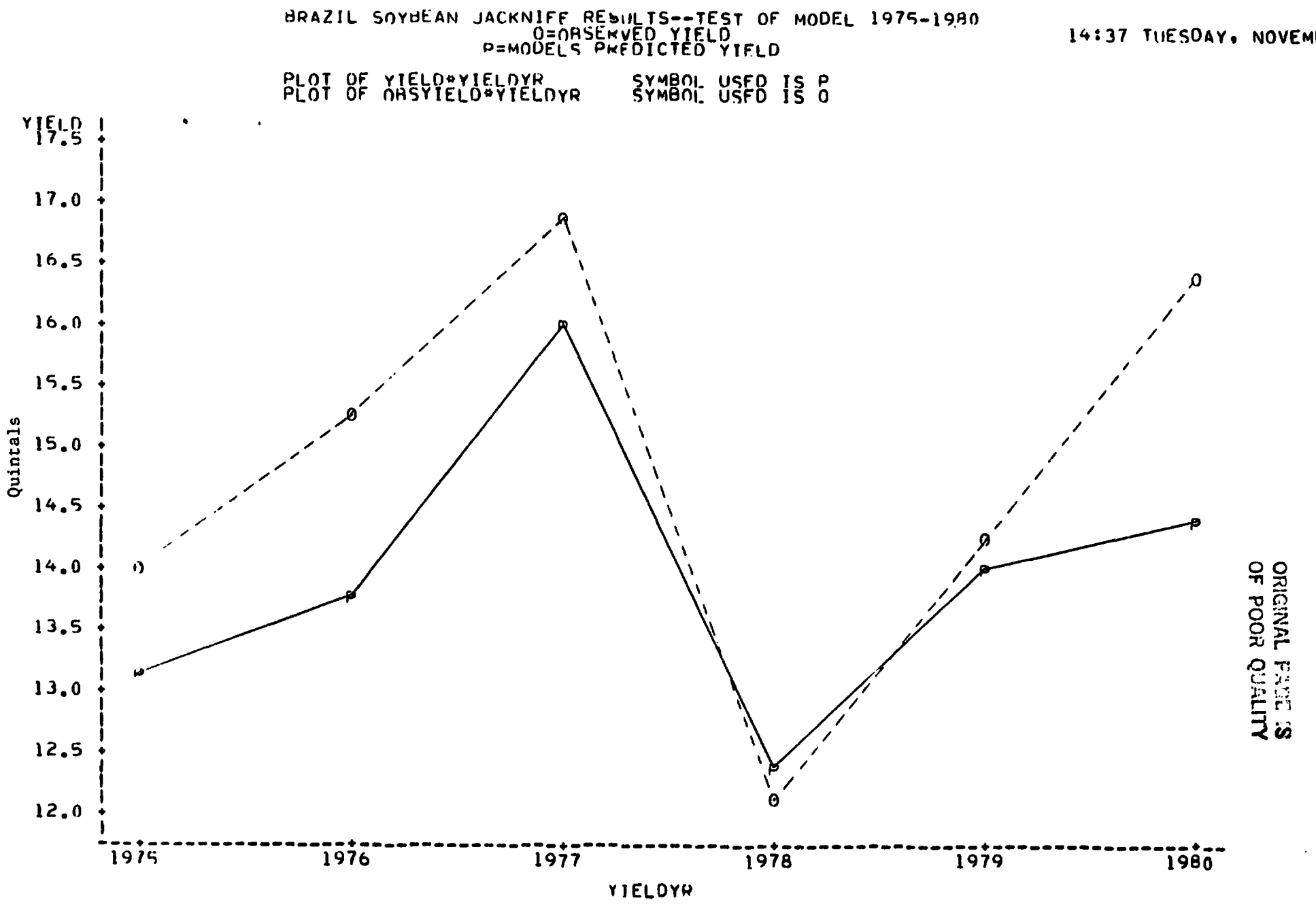


Figure 4. State of Mato Grosso Soybean Model.

BRAZIL SOYBEAN JACKNIFE RESULTS--TEST OF MODEL 1975-1980
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

14:37 TUESDAY,

| BETA2 | BEGMDLYR | ENDMDLYR | YIELDYR | YIELD | OBSYIELD | RSQ | PDER | DFRES | MSRES | BETA1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.52783 | 1976 | 1980 | 1975 | 11.6265 | 11.83 | 0.761662 | 0.36225 | 29 | 3.23711 | 13.900 |
| 3.44230 | 1975 | 1980 | 1976 | 10.7882 | 13.45 | 0.795559 | 0.59274 | 29 | 2.80618 | 13.674 |
| 3.47177 | 1975 | 1980 | 1977 | 14.3705 | 10.58 | 0.778618 | 1.05210 | 29 | 3.03799 | 14.155 |
| 2.67107 | 1975 | 1980 | 1978 | 15.9830 | 12.43 | 0.859119 | 0.23152 | 29 | 1.95932 | 14.336 |
| 2.98822 | 1975 | 1980 | 1979 | 17.4271 | 16.85 | 0.772079 | 0.55237 | 29 | 2.94903 | 14.145 |
| 3.16776 | 1975 | 1979 | 1980 | 16.1272 | 17.54 | 0.755441 | 0.36431 | 29 | 3.11795 | 13.879 |

| BETA3 | BETA4 | BETA5 | BETA6 | CONRIB1 | CONRIB2 | CONRIB3 | CONRIB4 | CONRIB5 | CONRI |
|---|---|---|---|---|---|---|---|---|---|
| 5.35628 | -2.1065 | 0.0171992 | 0.0110723 | 13.9006 | 0 | 0 | 0 | -1.7948 | -0.47 |
| 5.63172 | -1.6158 | 0.0213146 | 0.0070771 | 13.6744 | 0 | 0 | 0 | -3.2946 | 0.40 |
| 5.53279 | -2.3067 | 0.0186637 | 0.0068621 | 14.1556 | 0 | 0 | 0 | 1.1363 | -0.92 |
| 6.09044 | -2.2149 | 0.0156629 | 0.0126482 | 14.3360 | 0 | 0 | 0 | -0.0332 | 1.68 |
| 5.83360 | -1.7355 | 0.0142275 | 0.0111423 | 14.1454 | 0 | 0 | 0 | 1.4005 | 1.88 |
| 5.61586 | -2.1980 | 0.0176922 | 0.0098263 | 13.8794 | 0 | 0 | 0 | 2.1610 | 0.08 |



Table 5. Results of Jackknife Test for State of Minas Gerais Soybean Model.

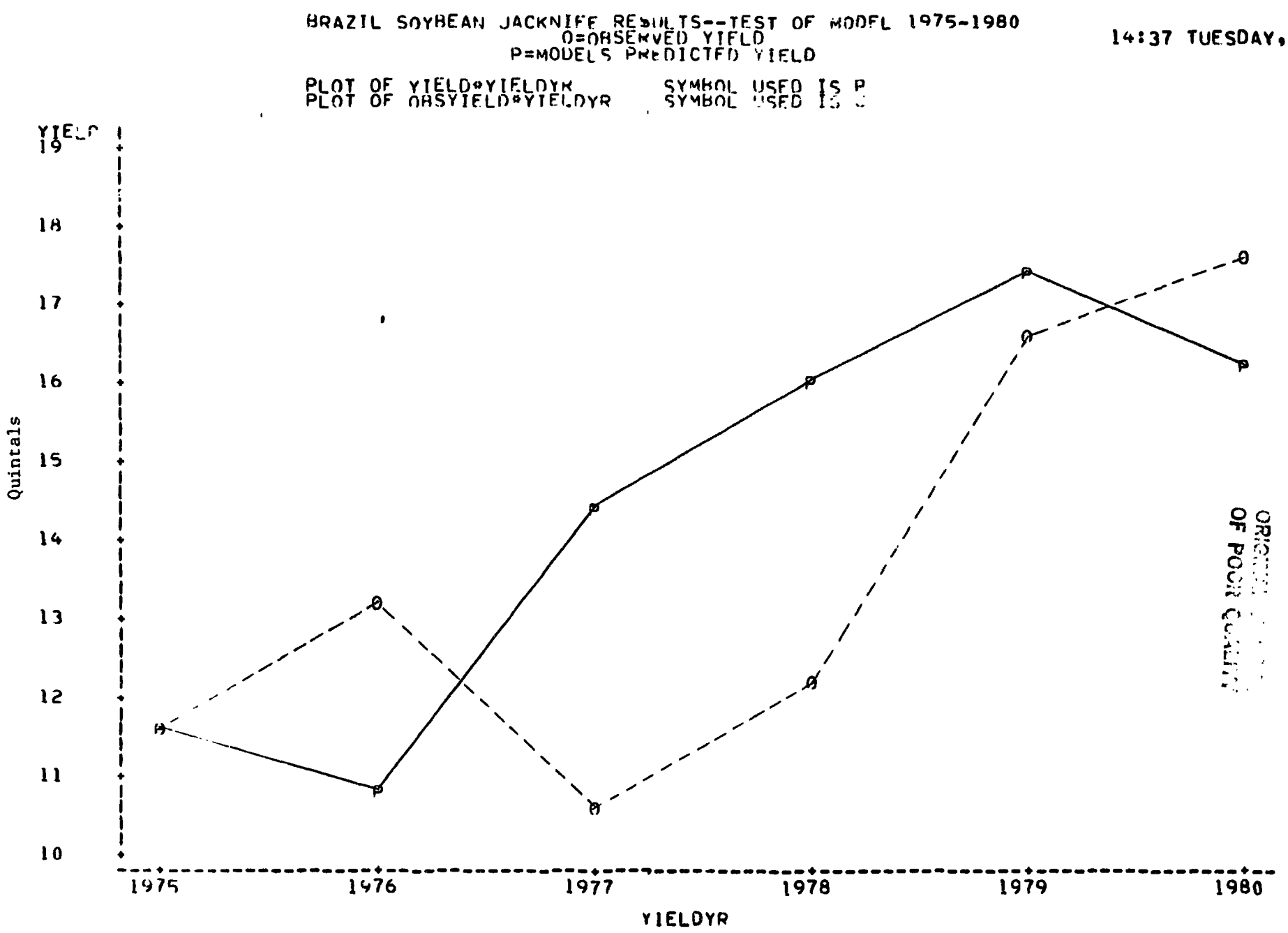


Figure 5. State of Minas Gerais Soybean Model.

BRAZIL SOYBEAN JACKNIFE RESULTS--TEST OF MODEL 1975-1980
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

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| BETA1 | BEGMDLYR | ENDMDLYR | YIELDYR | YIELD | OBSYIELD | RSQ | PDER | DFRES | MSRES |
|---|---|---|---|---|---|---|---|---|---|
| 15.0134 | 1976 | 1980 | 1975 | 15.4554 | 22.21 | 0.473183 | 0.30106 | 30 | 6.9167 |
| 14.8320 | 1975 | 1980 | 1976 | 14.6331 | 21.60 | 0.479810 | 0.66166 | 30 | 6.9021 |
| 15.2267 | 1975 | 1980 | 1977 | 16.5180 | 21.36 | 0.473163 | 2.45650 | 30 | 6.9887 |
| 15.5470 | 1975 | 1980 | 1978 | 13.5751 | 13.88 | 0.491461 | 0.62524 | 30 | 6.8368 |
| 15.3140 | 1975 | 1980 | 1979 | 14.1176 | 17.09 | 0.411667 | 0.55525 | 30 | 7.3589 |
| 15.0047 | 1975 | 1979 | 1980 | 16.6808 | 22.40 | 0.415470 | 0.31043 | 30 | 7.2039 |

| BETA2 | BETA3 | BETA4 | BETA5 | CONRIB1 | CONRIB2 | CONRIB3 | CONRIB4 | CONRIB5 | RUN |
|---|---|---|---|---|---|---|---|---|---|
| 2.39441 | -3.2069 | 0.0155437 | 0.0101771 | 15.0134 | 0 | 0 | 0.4668 | -0.02474 | 1 |
| 2.26819 | -2.7930 | 0.0204606 | 0.0052118 | 14.8320 | 0 | 0 | -0.6709 | 0.47204 | 2 |
| 2.29322 | -3.3582 | 0.0166398 | 0.0074985 | 15.2267 | 0 | 0 | 2.0305 | -0.73919 | 3 |
| 1.45144 | -3.4333 | 0.0162353 | 0.0126083 | 15.5470 | 0 | 0 | -1.5107 | -0.46120 | 4 |
| 1.86183 | -2.9595 | 0.0161446 | 0.0103711 | 15.3140 | 0 | 0 | -1.3774 | 0.18090 | 5 |
| 2.04191 | -3.3444 | 0.0172110 | 0.0084098 | 15.0047 | 0 | 0 | 1.0332 | 0.64299 | 6 |



Table 6. Results of Jackknife Test for State of Parana Soybean Model.

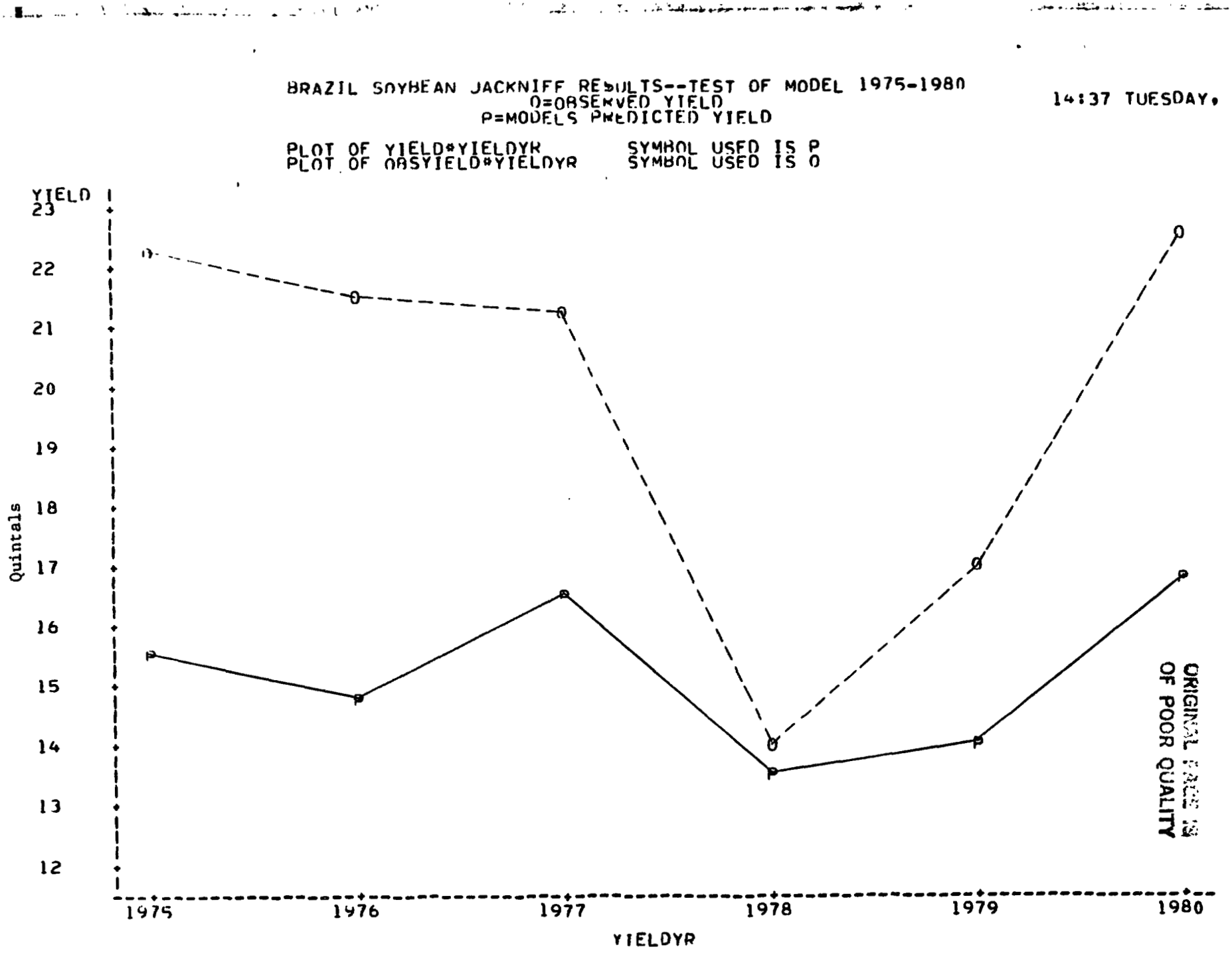


Figure 6. State of Parana Soybean Model.

BRAZIL SOYBEAN JACKNIFE RESULTS--TEST OF MODEL 1975-1980
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

14:37 TUESDAY, NOV

| BETA2 | BEGMDLYR | ENDMDLYR | YIELDYR | YIELD | OBSYIELD | RSQ | PDER | DFRES | MSRES | BETA1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.52783 | 1976 | 1980 | 1975 | 14.1255 | 15.06 | 0.761662 | 0.165034 | 29 | 3.23711 | 13.9006 |
| 3.44230 | 1975 | 1980 | 1976 | 14.7959 | 15.50 | 0.795559 | 0.155796 | 29 | 2.80618 | 13.6744 |
| 3.47177 | 1975 | 1980 | 1977 | 15.6346 | 16.47 | 0.778618 | 0.203560 | 29 | 3.03799 | 14.1556 |
| 2.67107 | 1975 | 1980 | 1978 | 13.4020 | 13.24 | 0.859119 | 0.148729 | 29 | 1.95932 | 14.3360 |
| 2.98822 | 1975 | 1980 | 1979 | 12.5524 | 9.00 | 0.772079 | 0.344852 | 29 | 2.94903 | 14.1454 |
| 3.16776 | 1975 | 1979 | 1980 | 13.2554 | 14.34 | 0.755441 | 0.172344 | 29 | 3.11795 | 13.8794 |

| BETA3 | BETA4 | BETA5 | BETA6 | CONRIB1 | CONRIB2 | CONRIB3 | CONRIB4 | CONRIB5 | CONRIB6 |
|---|---|---|---|---|---|---|---|---|---|
| 5.35628 | -2.1065 | 0.0171992 | 0.0110723 | 13.9006 | 0 | 0 | 0 | 0.0867 | 0.13829 |
| 5.63172 | -1.6158 | 0.0213146 | 0.0070771 | 13.6744 | 0 | 0 | 0 | 1.1221 | -0.00051 |
| 5.53279 | -2.3067 | 0.0186637 | 0.0068621 | 14.1556 | 0 | 0 | 0 | 1.1534 | 0.32558 |
| 6.09044 | -2.2149 | 0.0156629 | 0.0126482 | 14.3360 | 0 | 0 | 0 | -0.2519 | -0.68213 |
| 5.83360 | -1.7355 | 0.0142275 | 0.0111423 | 14.1454 | 0 | 0 | 0 | -1.7498 | 0.15681 |
| 5.61586 | -2.1980 | 0.0176922 | 0.0098263 | 13.8794 | 0 | 0 | 0 | -0.4063 | -0.21771 |



Table 7. Results of Jackknife Test for State of Rio Grande do Sul Soybean Model.

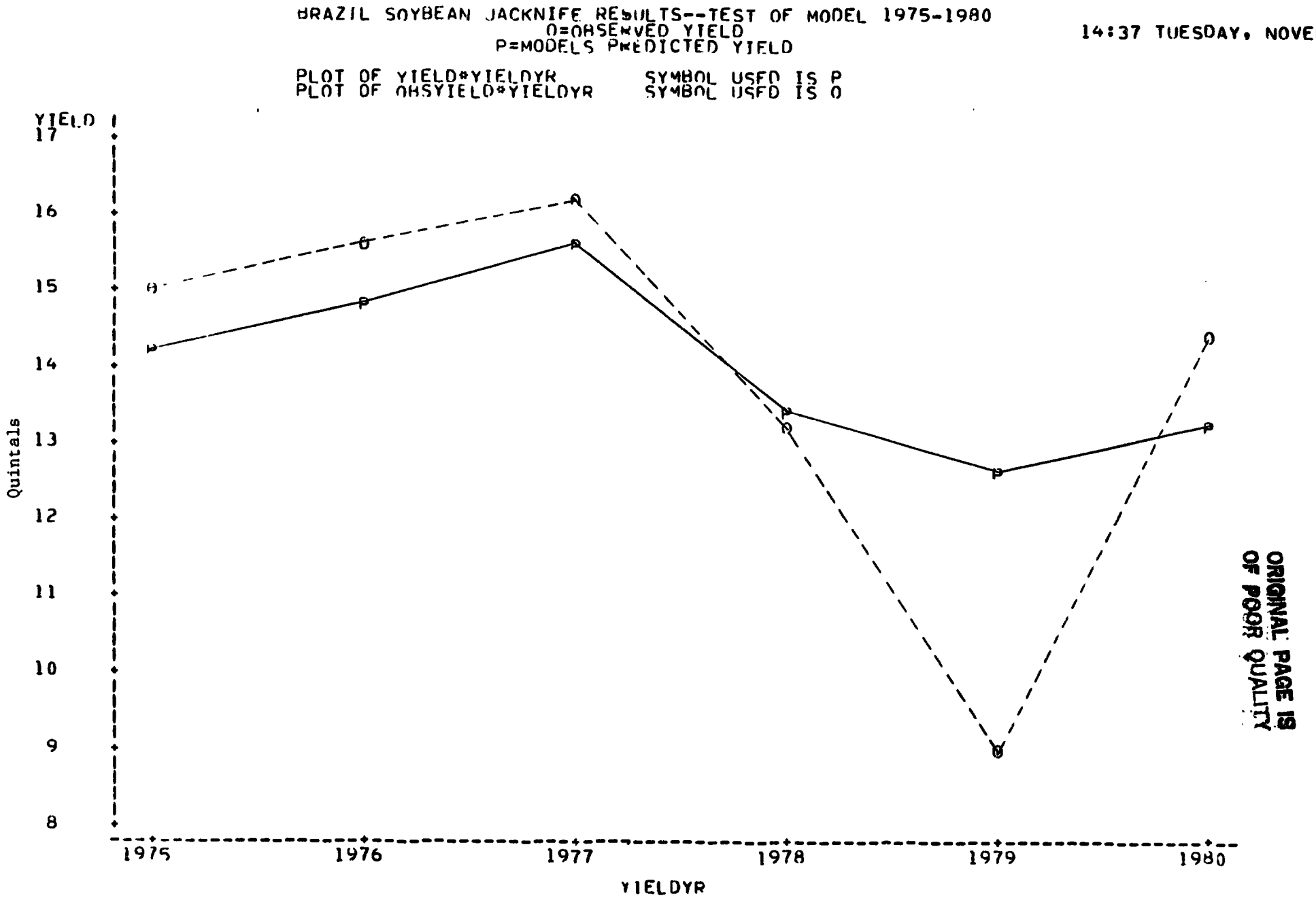


Figure 7. State of Rio Grande do Sul Soybean Model.

BRAZIL SOYBEAN JACKNIFE RESULTS--TEST OF MODEL 1975-1980
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

14:37 TUESDAY, N

| BETA1 | BEGMDLYR | ENDMDLYR | YIELDYR | YIELD | OBSYIELD | RSQ | PDER | DFRES | MSRE |
|---|---|---|---|---|---|---|---|---|---|
| 13.4603 | 1976 | 1980 | 1975 | 13.3204 | 12.92 | 0.717379 | 0.175641 | 30 | 3.710 |
| 13.3417 | 1975 | 1980 | 1976 | 14.3112 | 12.08 | 0.769657 | 0.141229 | 30 | 3.056 |
| 13.6101 | 1975 | 1980 | 1977 | 14.8679 | 13.59 | 0.729827 | 0.196828 | 30 | 3.583 |
| 13.8829 | 1975 | 1980 | 1978 | 13.3216 | 11.11 | 0.810870 | 0.153306 | 30 | 2.542 |
| 13.7977 | 1975 | 1980 | 1979 | 12.5884 | 8.94 | 0.740627 | 0.202610 | 30 | 3.244 |
| 13.4365 | 1975 | 1979 | 1980 | 13.8017 | 13.81 | 0.704207 | 0.156419 | 30 | 3.645 |

| BETA2 | BETA3 | BETA4 | BETA5 | CONRIB1 | CONRIB2 | CONRIB3 | CONRIB4 | CONRIB5 | RUN |
|---|---|---|---|---|---|---|---|---|---|
| 3.96114 | 5.78579 | 0.0172286 | 0.0121866 | 13.4603 | 0 | 0 | 0.17445 | -0.31434 | |
| 3.78019 | 5.96829 | 0.0215739 | 0.0077218 | 13.3417 | 0 | 0 | 1.04180 | -0.07226 | |
| 3.77858 | 5.93564 | 0.0170772 | 0.0104443 | 13.6101 | 0 | 0 | 0.96445 | 0.24337 | |
| 3.08356 | 6.53010 | 0.0155878 | 0.0135404 | 13.8829 | 0 | 0 | 0.14771 | -0.70895 | |
| 3.30340 | 6.19264 | 0.0133421 | 0.0118091 | 13.7977 | 0 | 0 | -0.76296 | -0.44631 | |
| 3.58765 | 6.05724 | 0.0169946 | 0.0109705 | 13.4365 | 0 | 0 | 0.09967 | 0.26555 | |



Table 8. Results of Jackknife Test for State of Santa Catarina Soybean Model.

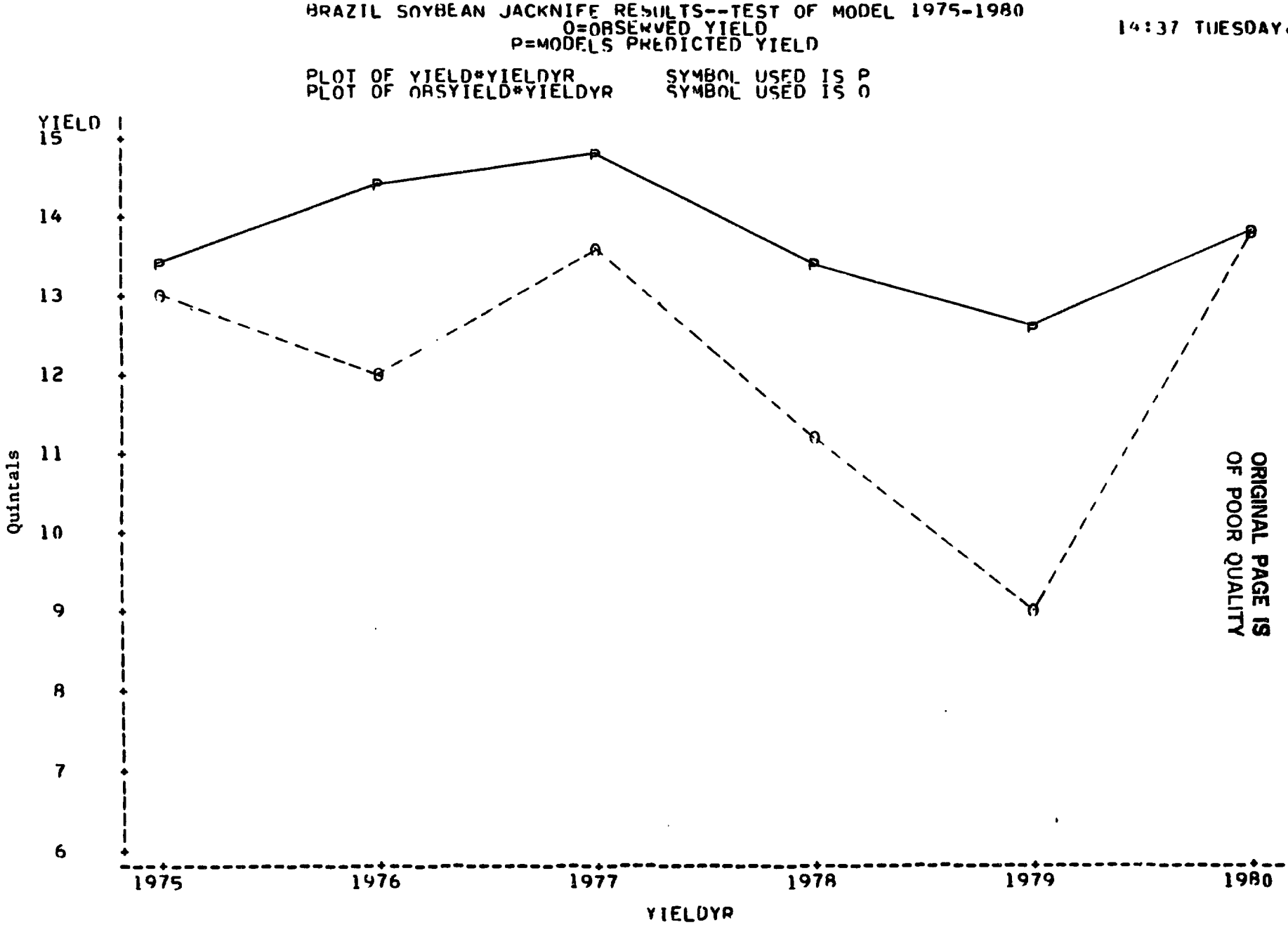


Figure 8. State of Santa Catarina Soybean Model.

BRAZIL SOYBEAN JACKNIFE RESULTS--TEST OF MODEL 1975-1980
O=OBSERVED YIELD
P=MODELS PREDICTED YIELD

14:37 TUESDAY, NO

| BETA1 | BEGMDLYR | ENDMDLYR | YIELDYR | YIELD | OBSYIELD | RSQ | PDER | DFRES | MSRES |
|---|---|---|---|---|---|---|---|---|---|
| 14.6383 | 1976 | 1980 | 1975 | 15.9285 | 17.33 | 0.637620 | 0.38306 | 30 | 4.75778 |
| 14.3930 | 1975 | 1980 | 1976 | 15.3455 | 19.42 | 0.678872 | 0.71525 | 30 | 4.26091 |
| 14.7104 | 1975 | 1980 | 1977 | 15.4753 | 17.09 | 0.662696 | 1.52123 | 30 | 4.47449 |
| 14.8335 | 1975 | 1980 | 1978 | 10.9747 | 14.00 | 0.789632 | 0.57203 | 30 | 2.82819 |
| 14.7135 | 1975 | 1980 | 1979 | 13.2745 | 15.83 | 0.678658 | 0.28692 | 30 | 4.01920 |
| 14.5054 | 1975 | 1979 | 1980 | 16.1914 | 19.79 | 0.647278 | 0.46569 | 30 | 4.34704 |

| BETA2 | BETA3 | BETA4 | BETA5 | CONRIB1 | CONRIB2 | CONRIB3 | CONRIB4 | CONRIB5 | RUNNUMI |
|---|---|---|---|---|---|---|---|---|---|
| 4.61634 | -2.8312 | 0.0156519 | 0.0103842 | 14.6383 | 0 | 0 | 0.0802 | 1.2100 | 1 |
| 4.92185 | -2.3303 | 0.0195468 | 0.0067112 | 14.3930 | 0 | 0 | -0.1416 | 1.0941 | 2 |
| 4.81999 | -2.7910 | 0.0157593 | 0.0098735 | 14.7104 | 0 | 0 | 1.7553 | -0.9905 | 3 |
| 5.56485 | -2.7075 | 0.0157852 | 0.0141960 | 14.8335 | 0 | 0 | -2.6461 | -1.2127 | 4 |
| 5.26362 | -2.2792 | 0.0137531 | 0.0128504 | 14.7135 | 0 | 0 | -0.6792 | -0.7598 | 5 |
| 4.98085 | -2.8131 | 0.0169201 | 0.0098561 | 14.5054 | 0 | 0 | 0.5480 | 1.1380 | 6 |



Table 9. Results of Jackknife Test for State of Sao Paulo Soybean Model.

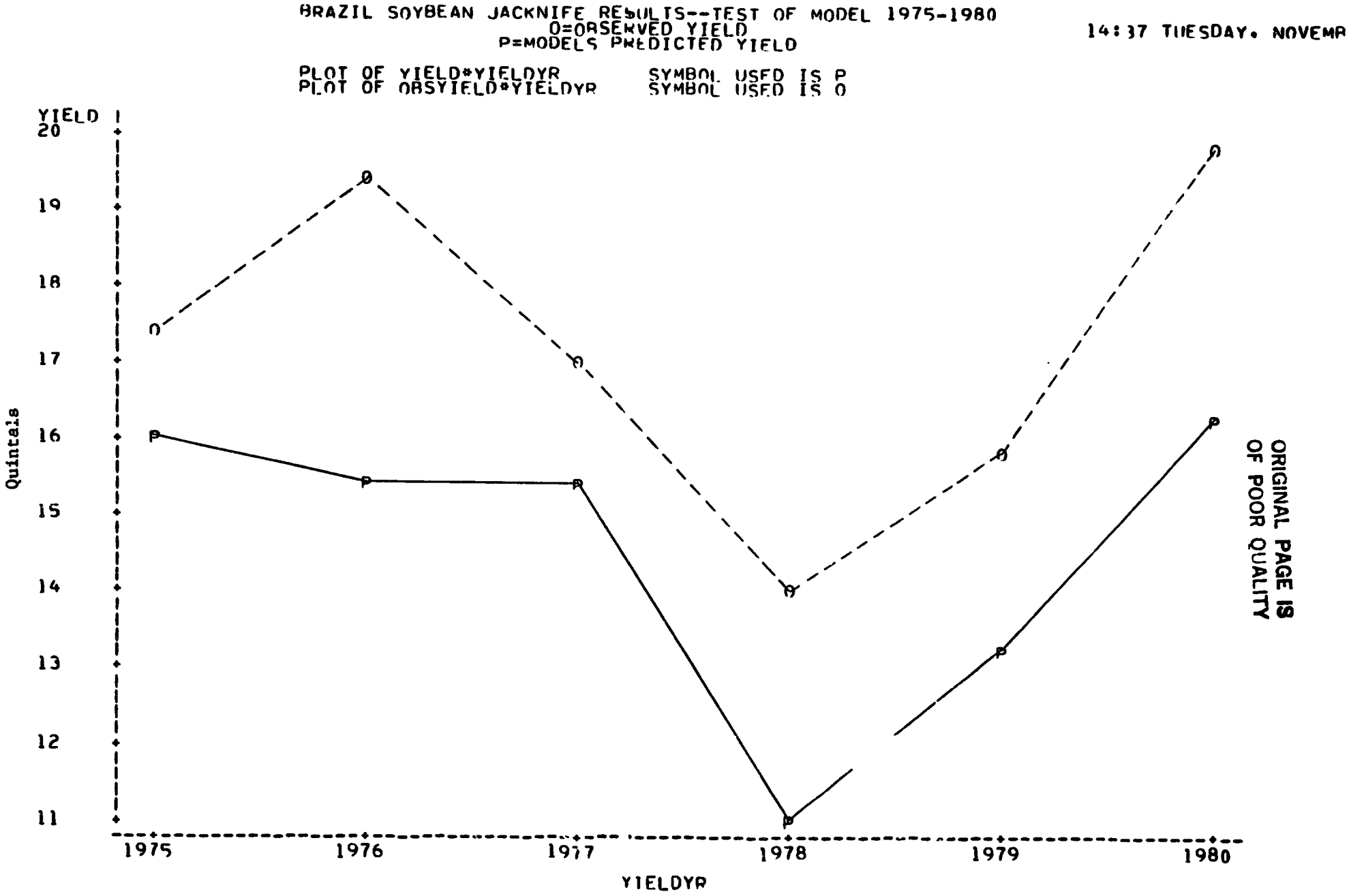


Figure 9. State of Sao Paulo Soybean Model.