PREDICTING YIELD VARIABILITY OF MAIZE SOWN OUT OF SEASON WITH THE CERES-MAIZE MODEL

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INTRODUCTION

In recent years, maize has become one of the main alternative crops for the Autumn-Winter growing season. Maize sown out of season (called "Safrinha" in Portuguese) in the State of São Paulo has increased from 284,000 ha in 1992 to 341,000 ha in 2001 (Tsunechiro, 2002). It is a high-risk crop, mainly due to the varying climatic conditions. In the State of São Paulo, the weather is characterized by abundant precipitation from October to February and insufficient and variable precipitation from March to September. Besides water deficits, sub-optimum temperatures and sunshine hours are common during the Autumn-Winter growing season, causing a reduction in yield potential.

For efficient agricultural management, crop models can be used as they can account for annual production variability associated with weather variability and interaction with other factors. Simulations can also be conducted during the growing season for yield forecasting, using the most recently recorded weather data. What may be of interest to a decision maker as well as the farmer is the change in distribution of the projected outcome as more and more "unknown" weather is replaced with observed weather from the current growing season. The closer the forecast is conducted towards the end of the growing season, the smaller the number of uncertain weather days. At the same time the predicted yield variability should decrease until the variance approaches zero, once all unknown weather has been replaced by observed weather data from the current growing season (Thornton et al., 1997). If accurate estimates of crop yield could be obtained prior to harvest, decision makers would have time to take actions that might be necessary to deal with either a surplus or deficit crop production. During a good season, with above average yields, decisions might have to be made regarding the disposal of the surplus; while during a poor season, with below average yields in some districts, it might be necessary to arrange for transportation of grain from the surplus to the deficit areas.

The goal of this study was to predict yield variability of maize sown out of season in Piracicaba, SP, Brazil. We used the CERES-Maize model to conduct seasonal analyses using historical weather data (Thornton et al., 1995) and to estimate yield variability of maize sown out of season in Piracicaba-SP region, Brazil.

MATERIAL AND METHODS

Three field experiment were conducted during 2001 and 2002 at the Escola Superior de Agricultura Luiz de Queiroz, University of São Paulo, in Piracicaba, SP, Brazil (latitude 22°.43' S, longitude 47 °.24' W). Four maize cultivars were sown out of season, on March 15th, 2001 under irrigated conditions. The cultivars included AG9010 (very short season), DAS CO32 and Exceler (short season) and DKB 333B (normal season). On March 13th, 2002 two experiments were planted with the same cultivars. One experiment was conducted under rainfed conditions, while the other experiment was irrigated. The three experiments were randomized with 4 replications. The soil was a Typic Eutrudox and weather data were obtained from the agrometeorology automatic station of the "Escola Superior de Agricultura Luiz de Queiroz". Experiments were fertilized based on soil analysis results. Weeds and main pest were controlled.

The latest version of the CERES-Maize model, included in DSSAT v4.0 was calibrated and evaluated (Jones et al., 2003; Wilkens et al., 2003). The calibration coefficients were obtained in sequence, starting with the phenological development parameters, followed by the crop growth parameters. This order was required because of the dependence of the latter parameters on the performance of the vegetative and reproductive development parameters. An iterative procedure (Hunt et al., 1993) was used to select the most appropriate value for each phenological and development parameter. Emergence, flowering, and maturity dates, growth analysis data, yield and yield components were used to calibrate and to evaluate the performance of the CERES-Maize model.

After model evaluation, yield estimation for the four cultivars was conducted. For the seasonal analyses, 25 years of daily weather records, including maximum and minimum air temperature, solar radiation and rainfall, were used and combined with the weather recorded for 2002. Yield forecasts were conducted nine times during the current growing season. The first forecast was obtained with daily weather data from January 1st until March 31st for 2002, followed by 25 years of historical weather data. For the second forecast observed weather data until April 15th, 2002 were used. Similarly, forecasts were conducted every 16 days from April 30th until July 31st.

Analyses were conducted for each forecast dates and the mean and standard deviations for yield were determined.

RESULTS

Yield predictions for 2002 for the four maize cultivars sown out of season are shown in Figure 1. A high yield variability was observed as shown by the standard deviation for the early yield predictions conducted during April and May. At the start of growing season yield can not yet be determined and is based on 25 years of yield simulations. The high variability shown at the start of the growing season confirms the high risk associated with growing maize out of season under rainfed conditions.

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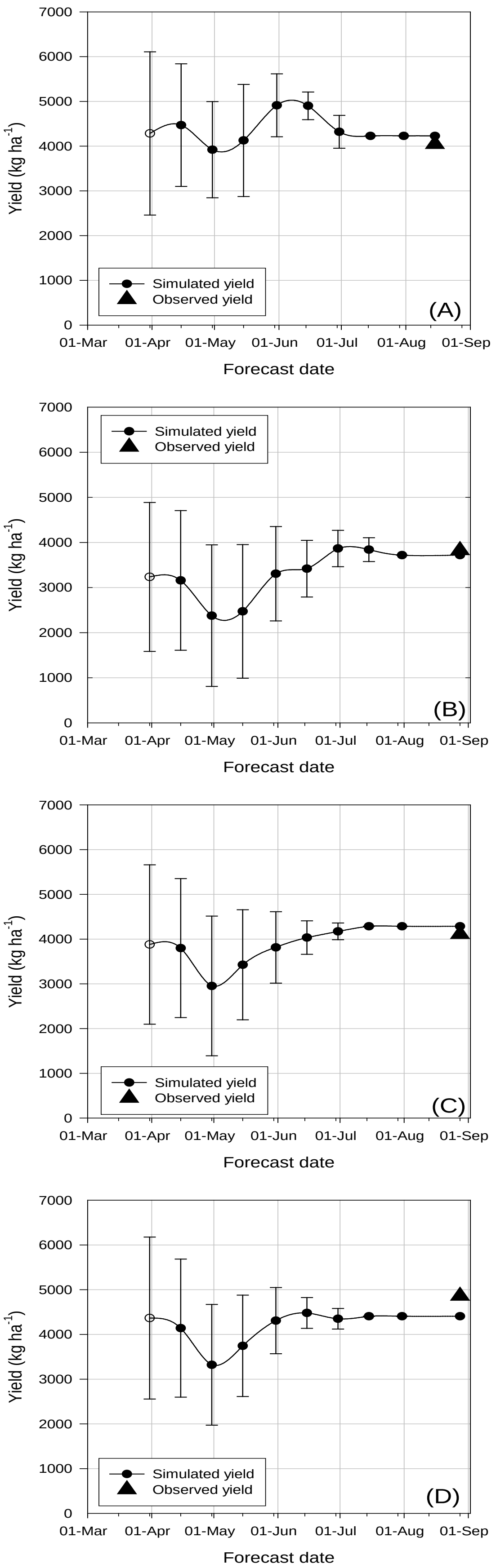

Figure 1. Average forecasted yield and standard deviation for 2002 as a function of forecast date and observed yield (kg ha^{-1}) for cultivars AG9010 (A), DKB 333B (B), DAS CO32 (C) and Exceler (D).

When the simulations were conducted considering a broader period with actual weather records for 2002, the standard deviation of yield decreased for the 4 cultivars under study. For the cultivars AG9010, DAS CO32 and Exceler the estimated yield had a standard deviation that was close to zero on July 15th (Figure 1-A, C, D), while for the cultivar DKB 333B, with a normal growing season duration, the standard deviation reached almost zero on July 31st (Figure 1-B). Thus, for the short season cultivars yield is determined earlier and yield forecasts can be done earlier than for normal season cultivars.

Yield for the normal season cultivar DKB 333B grown under rainfed conditions was less than for the other cultivars. The CERES-Maize model was able to predict these yield differences as well (Figure 1-B). A normal season cultivar is more exposed to adverse weather conditions including precipitation, temperature and solar radiation than a short season cultivar, resulting in a lower yield.

CONCLUSIONS

An accurate yield forecast could be provided more than one month prior to harvest for four maize cultivars, grown out of season in Piracicaba, SP, Brazil.

For rainfed conditions, the very short and short season maize cultivars produced a higher yield than the normal season cultivar.

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