Coupling Crop Simulation Models with Generated Weather Data to Assess Crop Management Options

Afshin Soltani1,* and Gerrit Hoogenboom2

1Department of Agronomy and Plant Breeding, Gorgan University of Agricultural Sciences
Gorgan 49138-15739, Iran afsoltani@yahoo.com

2Department of Biological and Agricultural Engineering, the University of Georgia, Griffin
Georgia 30223, USA

*Corresponding author: Iran afsoltani@yahoo.com

Abstract

The objective of this study was to evaluate the suitability of weather data generated by the weather generators WGEN and SIMMETEO as input for crop simulation models in order to determine the best option(s) among a number of different crop management practices. Five locations across Iran with different climates were selected for the study. The wheat, maize, and soybean models of the Decision Support System for Agrotechnology Transfer (DSSAT) were applied in this study, using 30 years of observed weather data and 90 years of weather data generated by WGEN and SIMMETEO. Irrespective of some significant differences between simulated yield based on observed weather data and those based on weather data generated by WGEN and SIMMETEO, a similar conclusion could be drawn about the best cultivar, planting date, plant density, and irrigation threshold. It can be concluded based on the results of this study that for many DSSAT applications where only relative estimates or determination of the best option(s) rather than absolute values are required, weather data generated by either WGEN and SIMMETEO are accurate and adequate.

KEY WORDS: Weather generation, stochastic model, simulation model, decision support systems

Introduction

Many agronomic and environmental studies are conducted to determine crop characteristics and agronomic practices for maximizing crop production, optimizing natural resource use and minimizing environmental impact and pollution. Using crop simulation models is an efficient complement to experimental research. These models can be used for interpretation of results and analysis of the behavior of agronomic systems under diverse environmental conditions and management options. Investigations based on crop simulation models are faster and require less labor and other resources compared to experimental studies alone. Crop models are also helpful with respect to decision-making in sustainable farming systems (Boote et al., 1996).

The accuracy of the data simulated by crop models is dependent upon the quality of weather data that are used as input (Meinke et al., 1995). Several studies have been conducted to determine the quality of crop model simulations as influenced by the quality of input weather data (Richardson, 1985; Meinke et al., 1995; Mavromatis and Jones, 1998; Soltani et al., 2000; Sentelhas et al., 2001; Mavromatis and Hansen, 2001; Hartkamp et al., 2003; Soltani et al., 2004). In these studies, the absolute differences between simulated outputs using observed and generated weather data were considered as the number of significant differences or percentage of significant differences. However, for many crop model applications only relative estimates or selection of the best option(s) rather than absolute values are of prime importance. Therefore, irrespective of the significant absolute differences, crop models may be able to recognize the best option(s) among a number of different scenarios. So far no studies have been conducted that have evaluated the weather generators from this point of view.

The main objective of this study, therefore, was to evaluate the suitability of the generated weather data used as input to crop models to determine the best option(s) among a number of management practices.
Materials and methods

Three crop models that are part of DSSAT were used in this study (Tsuji et al., 1994; Jones et al., 2003; Hoogenboom et al., 2004). These included the crop models CERES-Wheat, CERES-Maize, and CROPGRO-Soybean. These models have been evaluated for a wide range of experimental practices and environmental conditions (Jones et al., 2003). They have also been calibrated and evaluated under Iranian conditions (Soltani, unpublished data). Hence, for the purpose of this paper we assume that physiological responses to environmental conditions are real and appropriate.

The weather generators used in this study were adaptations of WGEN (Richardson and Wright 1984) and SIMMETEO (Geng et al., 1986 and 1988) as implemented in WeatherMan (Pickering et al., 1994). Additional information is provided by Richardson (1985), Richardson and Wright (1984), Semenov et al. (1998) and Mavromatis and Hansen (2001), Geng et al. (1986 and 1988), and Soltani and Hoogenboom (2003a and 2003b).

For this study five sites in Iran were selected that have weather stations with long-term reliable historical daily data. They include Gorgan, Kermanshah, Isfahan, Ahwaz and Shiraz. These stations cover a wide geographical area and represent several climatic zones in Iran. A complete 30-year set of daily precipitation, maximum and minimum temperature and solar radiation was available for each location.

To create the synthetic weather series, the input parameters for the two weather generators were obtained from either the daily (WGEN) or monthly summaries (SIMMETEO) of 30 years of daily weather data. For each location, three 30-year daily time series were generated with WGEN and SIMMETEO using different 'seed numbers' to initialize each generation (cf. to Soltani and Hoogenboom, 2003). We had, therefore, three sources of weather data for each location, i.e., observed weather data, WGEN-generated weather data, and SIMMETEO-generated weather data.

Simulation 'experiments' were performed with different experimental factors including planting date, plant density and irrigation threshold. All experiments were simulated with the three types of weather data sources.

Results

Across simulation experiments and statistical tests, 20% of the comparisons between simulated yields using observed weather data and simulated yields using WGEN and SIMMETEO generated weather data were significant (data not shown). Similar numbers have been reported by others, e.g., Soltani et al., (2000), Sentelhas et al. (2001), Mavromatis and Hansen (2001) and Harkamp et al. (2003). In many applications of crop simulation models relative estimates of crop yield or other characteristics as affected by the number of different agronomic practices that are considered, e.g., for the determination of the best planting date, planting rate or cultivar. In such situations, the absolute significant or non-significant differences between simulated yields are often not important and the ranking is more critical. We evaluated the suitability of using generated weather data as input in crop simulations in these situations, i.e., the determination of the best option(s) among a number of different practices.

The response of maize yield to different planting dates simulated with either observed or generated data was similar (Figures 1a and 1b), although for some treatments the differences between weather data sources were considerable and statistically significant (data not shown). Using all three sources of weather data, the highest maize yield was obtained around 20 July for Gorgan and 1 July for Isfahan. For the earlier planting dates, the yields were lower and for the later planting dates a rapid decline in yield was simulated. For soybean, the highest yields were simulated on 10 March for Gorgan and 4 April for Isfahan while the differences between planting dates up to 20 April in Gorgan and 20 May in Isfahan were not significant based on their confidence intervals (Figure 1c and 1d). However, a sharp decline in yield was predicted for the later planting dates (Figures 1c and 1d). All three sources of weather data resulted in similar trends for planting date.

The wheat yield simulated with observed data for irrigated conditions in Kermanshah reached a minimum on 5 February (Figure 1e). The minimum yield on 5 February was caused by low temperatures that affected plant establishment due to increased winter-kill. A similar trend was
obtained with the generated weather data of WGEN and SIMMETEO. For rainfed conditions, the best planting date with all three weather data sources was around 8 October and yield decreased for later planting dates (Figure 3f). This shows that it is possible to determine optimum planting dates with generated weather using either WGEN or SIMMETEO.

The highest maize yield simulated with observed and generated weather data was obtained at a plant density of 17 plants m² (Figure 2a). While the yield response curve of WGEN was somewhat lower than SIMMETEO or observed data, its shape was similar. For soybean, the yield simulated with observed weather data increased with an increase in plant density and reached 95% of its maximum at a density of 67 plants m² (Figure 2b). In this case, similar trends were obtained using WGEN- and SIMMETEO-generated weather data.

By using observed and generated weather data, soybean yield increased with an increase in the threshold value up to 29% at Isfahan and 21% at Gorgan, while larger thresholds had no impact on yield (Figure 3). The response curves for all three sources of weather data were very close and it was relatively easy to determine the optimum irrigation threshold.

Conclusions

For DSSAT applications where determination of the best management option(s) rather than absolute values are required, generated weather data of both WGEN and SIMMETEO are accurate. This means that there is no difference between the methods used to estimate the parameters for the weather generators. This outcome is rather important, as WGEN requires daily weather data for estimating input parameters. In general, high quality long-term weather data are rare (especially in developing countries) and require a lot of resources for preparation.

References


Figure 1: Response of grain yield to planting date for maize and soybean at Gorgan and Isfahan and for wheat at Kermanshah under irrigated and rainfed conditions simulated with observed (O) weather data or weather data generated with WGEN (W) and SIMMETEO (S). Vertical bars indicate +/- 2 standard error calculated for yield simulated with observed data.
Figure 2: Response of grain yield to planting density for maize and soybean at Ahwaz simulated with observed (O) weather data or weather data generated with WGEN (W) and SIMMETEO (S). Vertical bars indicate +/- 2 standard error calculated for yield simulated with observed data.

Figure 3: Response of grain yield of soybean to the irrigation threshold level at Isfahan and Gorgan simulated with observed (O) weather data or weather data generated with WGEN (W) and SIMMETEO (S). Vertical bars indicate +/- 2 standard error calculated for simulated yield using observed data.