Crop Growth Models Can Effect Change – A Case History

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Abstract

The sorghum growth model, SORKAM, is used to illustrate the impacts a crop growth model can have in crop model development, risk assessment, crop physiology, crop phenology, and crop breeding. In some cases, e.g. risk assessment, a single function from the model was adequate to determine the probability of freeze before crop maturity. In other cases, e.g. the determination of rate and duration of grain fill, finding adequate methods of simulation provided a source-sink approach to rate of fill and a constant growing degree day summation for duration of grain fill for current hybrids. This led to identification of lines with genetically longer grain fill duration which have been shown to increase yields and seed size. Thus crop models can provide new ideas and products in a number of ways.

Media summary

The SORKAM, sorghum growth model has been used to determine freezing risk for sorghum and has led to identification of sorghum lines with genetically longer grain filling duration which will substantially increase grain yield.

Key words

Risk management, crop breeding, crop phenology, crop physiology, sorghum

Introduction

Crop growth models have been developed over the last 3 to 4 decades and there has been much discussion about their impact. We use the sorghum growth model, SORKAM, (Arkin et al., 1976, Rosenthal et al., 1989) to describe the impact a crop model can have on model development, risk assessment, crop phenology, and crop breeding. At the 1992 Symposium on ‘Agrometeorology of Sorghum and Millet in the Semi-Arid Tropics’(ICRISAT, 1984), Dr. John Monteith chaired the section on use of crop models. He asked each presenter to answer a series of questions about their models before making their presentations. These are condensed and paraphrased in Fig. 1. We use particularly the last question to provide examples of how SORKAM has led to a number of new ideas or new products.

Model development
- Constants of no biological or physical basis?
- Experimental material from one source?

Model operation
- Model becoming increasingly complex?
- Never tried to “tune” the model?

Model output
- Tested with independent data sets?
- Source or sink of ideas?

Figure 1. Questions asked by Dr. Monteith to determine validity and utility of each crop model.

Products derived from SORKAM

Freeze risk

Schaffer (1980) showed that if the duration of grain fill was measured not in days but in growing degree days, there was essentially no difference in duration of grain fill among hybrids differing in maturity or among widely different planting dates. This constant duration of grain fill was used with historical weather data to provide probabilities of the crop maturing before a freeze depending on when the crop flowered (Shroyer et al., 1987). Figure 2 shows one of the probability maps.

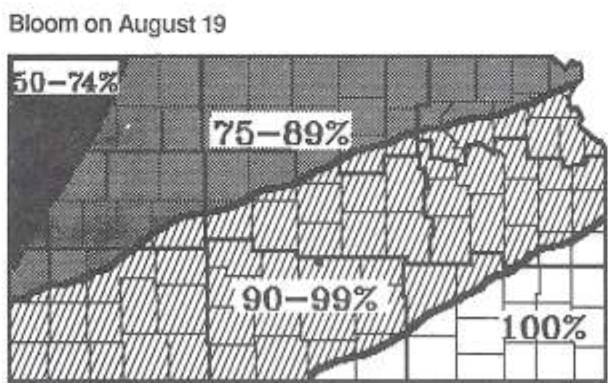

Figure 2. Probability of sorghum maturing before a freeze if half-bloom occurred on August 19.

Source/sink grain-fill routine

Sorghum has tremendous capability to compensate in the yield components of head number, seed/head, and seed size. SORKAM (Rosenthal et al., 1989) generally did too good a job of allowing yield component compensation. Heiniger et al. (1997) developed a source/sink approach to determining how much of current plant growth would be used in filling the grain. This approach gave much more realistic grain growth curves (Fig. 3) and greatly improved the capability of SORKAM to simulate yield under a range of conditions (Fig. 4).

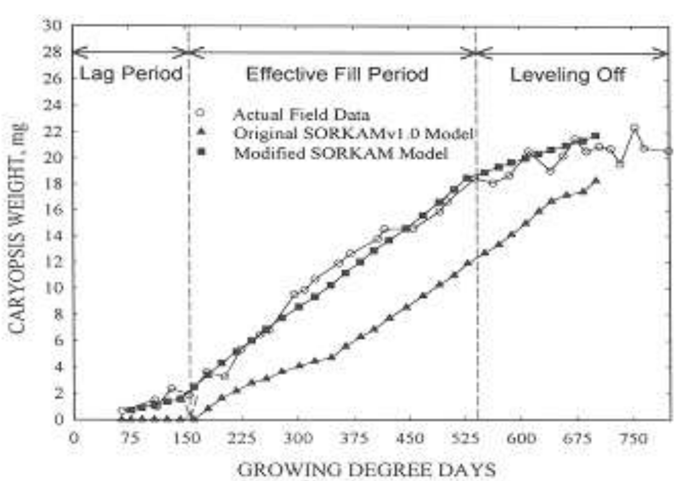

Figure 3. Caryopsis growth compared with the original SORKAM and the source/sink functions.

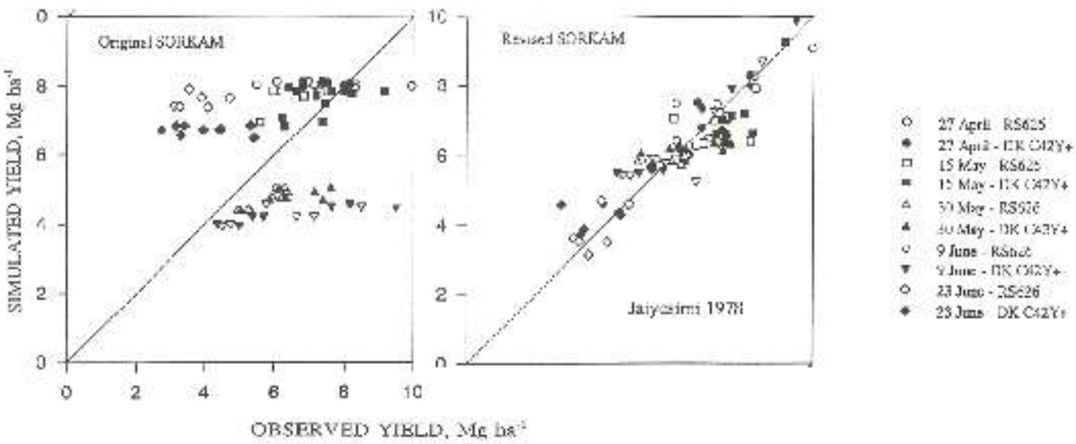

Figure 4. Comparison of simulated and actual grain yields before and after inclusion of the source/sink function.

Replanting guidelines

Because sorghum has such great capability for yield component compensation, marginal stands will often produce quite good yields. In addition, because low temperatures promote tillering, replanting often places the crop under environmental conditions that are less favourable for tillering, thus limiting the compensation. Replanting may also increase the risk for freeze damage at the end of the season. SORKAM was used to simulate three hybrids of differing maturity for a range of plant populations and planting dates using 30 years of weather data for 17 locations in the state. Results were provided in a decision aid (Vanderlip et al., 1995). Figure 5 shows an example comparison of expected yields from original 'poor stand' vs. 'replanted' crops.

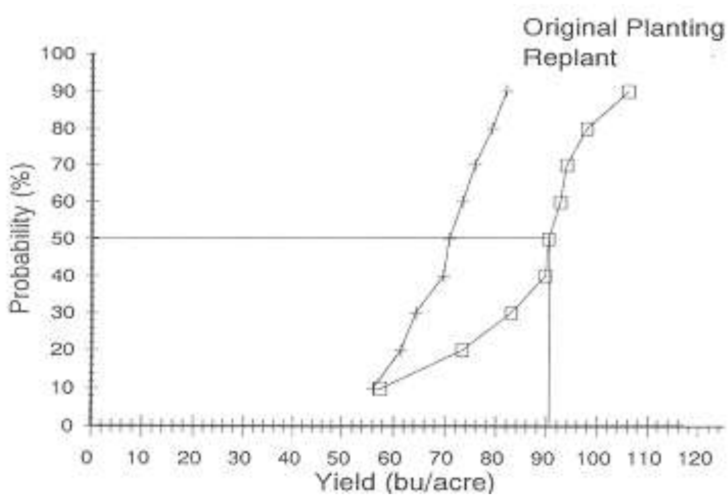

Figure 5. Comparison of yield probabilities for an original 15 May planting of a medium maturity hybrid which only resulted in 20,000 plants/acre (squares) and a 15 June replanting with an early hybrid at 60,000 plants/acre (pluses).

Breeding for increased grain fill

The determination that current commercial hybrids lacked variability in duration of grain fill when measured on a heat-unit basis led to the question of whether there was genetic variability for this trait. If so, and if it would lead to increased yield, why wasn't it already in the various public and private breeding programs in the U.S. and elsewhere. Simulation of yields for hybrids with increased grain fill duration (about 100 GDD) suggested that even under moisture limiting conditions yields would be increased substantially (Barten, 2001) Over 400 lines were screened and variability in duration of grain fill was found (Fig. 6). One of the lines was released as KS115 and has been used in producing experimental hybrids. Preliminary field results suggest that indeed yields can be increased, with the increases coming primarily through increased seed size (Tuinstra et al., 2001)

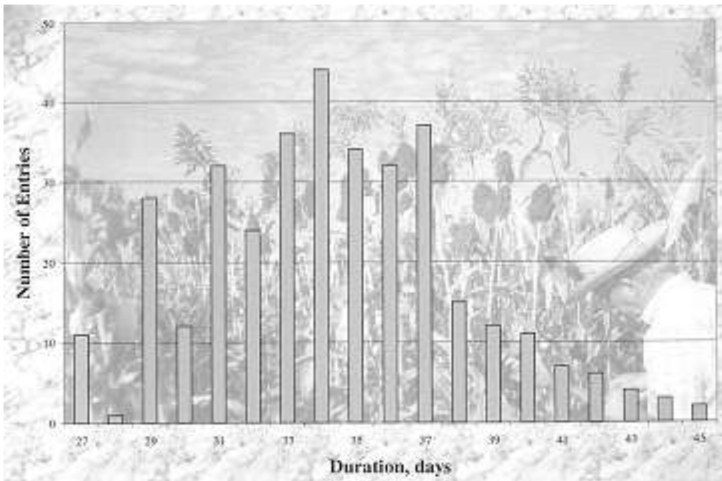

Figure 6. Distribution of duration of grain fill for lines grown under short-day, nearly constant temperature conditions in Mexico. The three hybrid controls filled grain for about 35 days.

Conclusions

Crop growth models can provide sources of new ideas and lead to improvements in determining risk in variable environments, improve understanding and simulation of crop phenology and physiology, and suggest and test the impact of specific breeding objectives.

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