Improving degree-day models for the flight phenology of western bean cutworm (Lepidoptera: Noctuidae)

Anthony A. Hanson[1], Roger D. Moon[1], Robert J. Wright[2], Thomas E. Hunt[2], and William D. Hutchison[1]
[1]Department of Entomology, University of Minnesota, St. Paul, MN
[2]Department of Entomology, University of Nebraska, Lincoln, NE

Introduction

- Western bean cutworm, *Striacosta albicosta* (Smith) (Lepidoptera: Noctuidae), is a native univoltine pest of corn and dry beans in North America.
- *S. albicosta* oviposit in midsummer; larvae in the corn ears can avoid pesticide applications.
- Scouting for egg masses is recommended at 25% annual moth flight (Fig. 1).
- Flight was previously predicted with a simple degree-day model beginning May 1st with base 10°C and accumulating 733 degree-days(°C) (Amad 1979).

Figure 1. WBC egg mass (left), WBC adult (right). Photos by Marlin E. Rice.

- Significant *S. albicosta* infestations have been observed beyond the previously described range in the west-central U.S (Michel et al. 2010).
- The starting date of May for degree-day accumulation may not account for insect development in early spring.
- We considered the effects of different lower and upper thresholds and start dates for degree-day (DD) models. We examined the effectiveness of the Ahmad and newly proposed models in Nebraska.

Methods

- Daily moth catch data were collected from black light traps in Aurora, Clay Center, Concord and North Platte, NE throughout 1981 to 2009 (model development location-years: *n* = 37; validation: *n* = 36).
- Daily temperatures were obtained from the Midwest Regional Climate Center to calculate DD for lower thresholds of 0-15.5°C, and upper thresholds of 20-30°C. Start dates were Jan 1 to May 1.
- Simple degree-day (daily average - lower threshold; average set to respective threshold if exceeded) and modified sine-wave methods were used for parameter combinations (Allen 1979; McMaster & Wilhelm 1997).
- Average degree-days predicting 25% flight were calculated to determine Julian dates of 25% moth flight at the Nebraska locations for each year.
- Concordance correlation coefficient (*CCC*) was calculated to assess agreement of predicted and observed dates of flight (Liao 2003). *CCC* values closer to 1 represent increasing agreement.
- Parameters from the 25% flight model with the highest CCC estimate were used to model the entire annual flight curve (PROC LIFEREG, SAS 9.4).

Results

- **Highest *CCC* for simple DD:** start date = 1 March, lower threshold = 3.3°C, upper threshold = 23.9 °C, 25% target = 1461 DD °C (Fig. 2).
- **Highest *CCC* for sine-wave DD:** start date = 1 Jan., lower threshold = 5.0°C, upper threshold = 22.8C, 25% target = 1256 DD °C (Fig. 2).
- The simple DD model had high agreement in model development and validation (Fig. 3).
- The sine-wave model performed poorly in validation location-years. (Fig. 3).

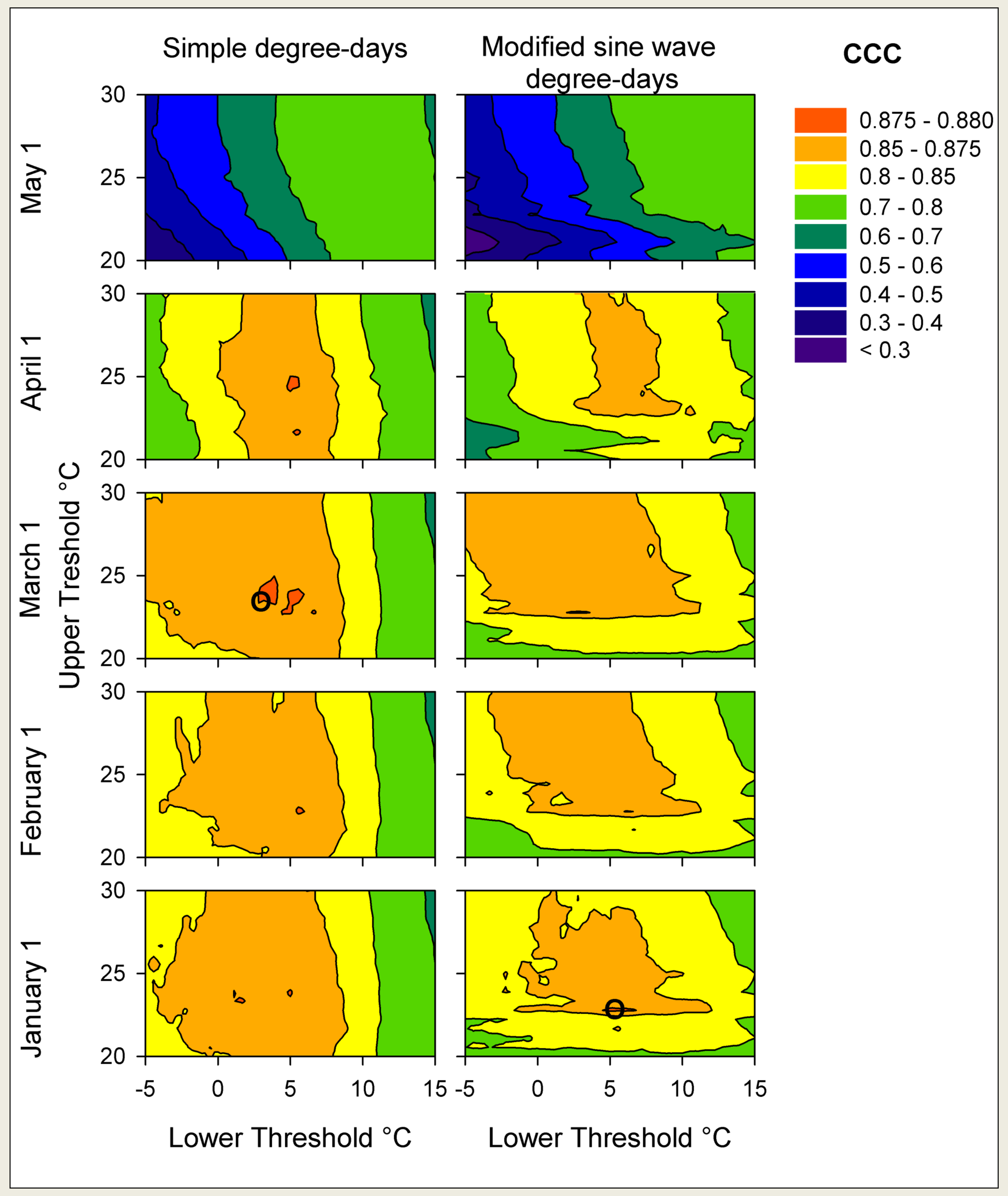

Figure 2: *CCC* for models at predicted 25% flight. A circle indicates the highest *CCC* for simple or sine-wave methods.

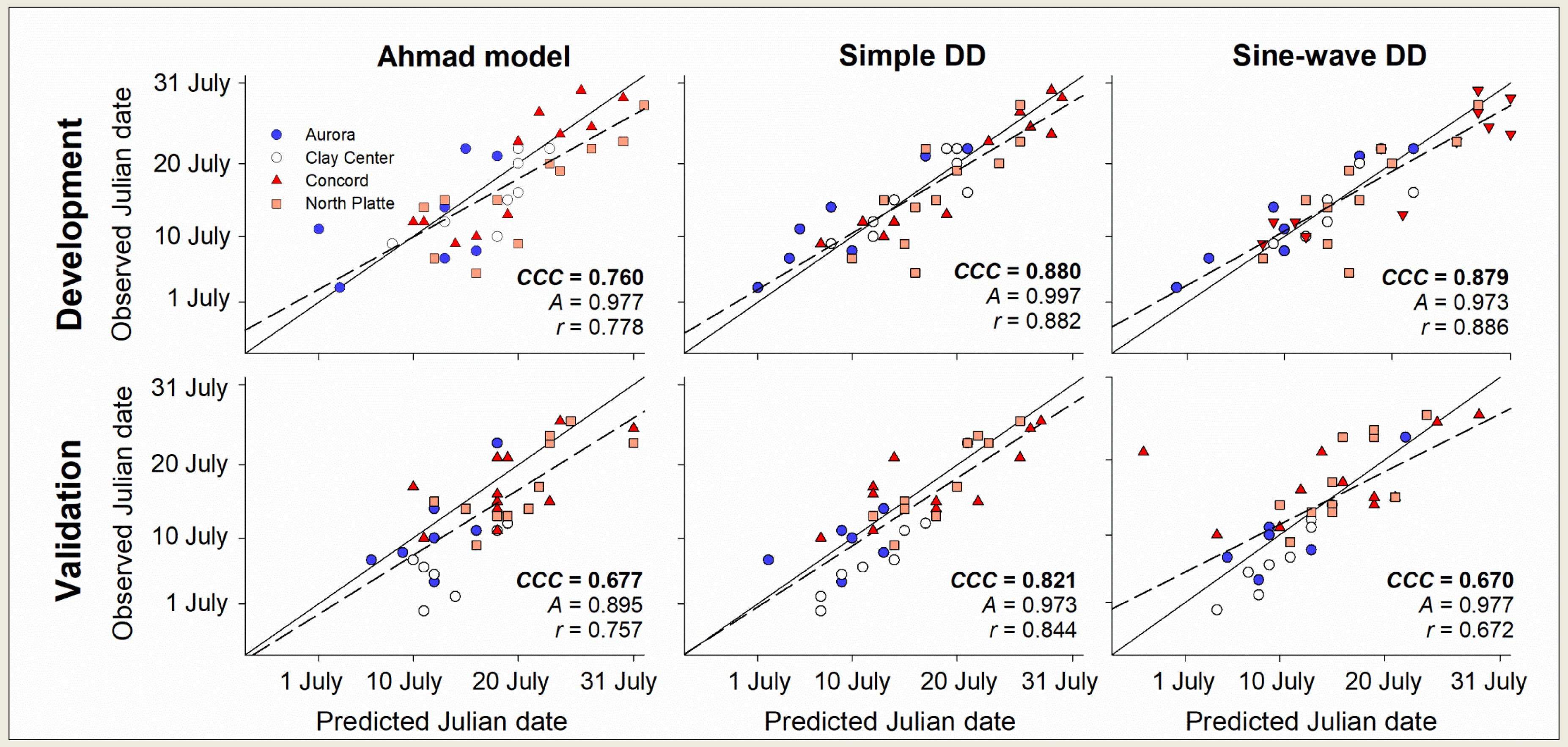

Figure 3: Observed days of 25% flight versus days predicted by three phenology models: the Ahmad (1979) model; the highest *CCC* simple DD model; and the highest *CCC* sine-wave model. Solid lines indicate perfect agreement (observed date equals predicted date). Dashed lines are least squares regression lines that indicate deviations from agreement. Overall agreement is characterized by concordance correlation coefficients (*CCC*), which depend on component measures of precision (Pearson's correlation coefficient, *r*) and accuracy (*A*).

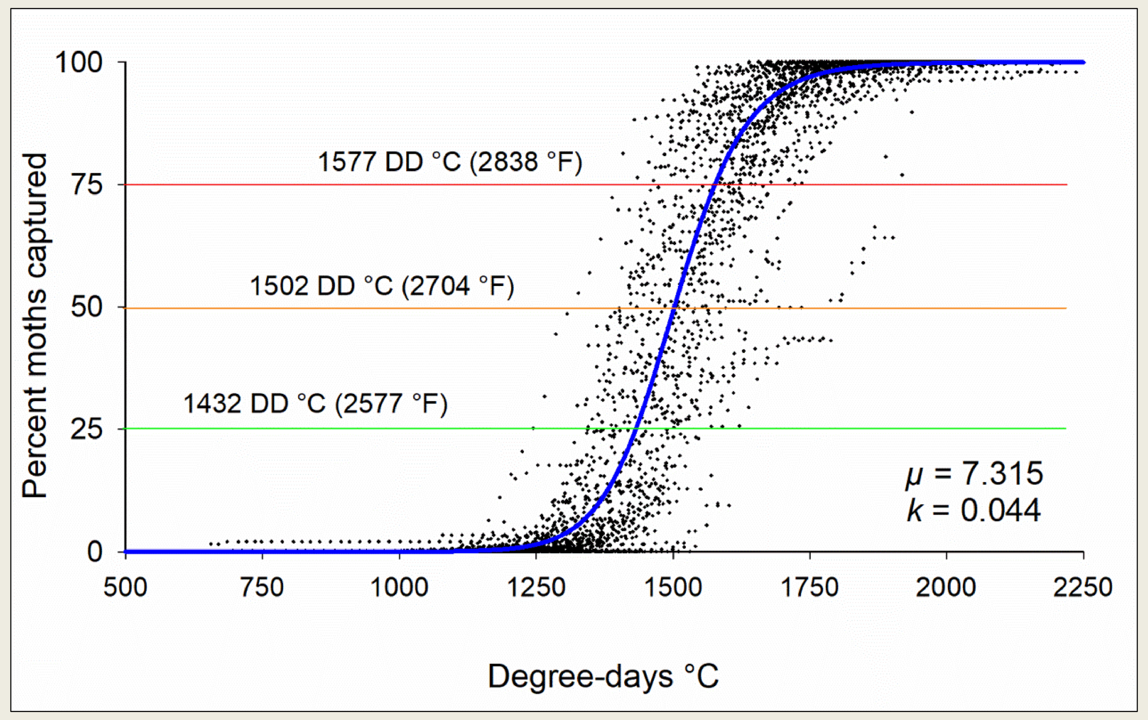

Figure 4: Cumulative flight fit with a log-logistic distribution (blue line) using highest *CCC* simple DD parameters where proportion of annual flight = $1 + e^{\left(\frac{\ln(D)-\mu}{s}\right)}$ and *D* = accumulated degree days.

- 25% flight predicted DD from the cumulative log-logistic model (1,432 °C) did not differ significantly from target DD by averaging of DD at dates of observed 25% flight (1461 °C). (Fig. 4).
- Agreement was also high for model development (*CCC* = 0.858) and validation (*CCC* = 0.844) using target DD from the cumulative model at 25% flight. (Hanson et al. 2016).

Discussion

- Lower thresholds near 3.3 °C were more appropriate than the previous 10 °C threshold.
- Temperatures under 10°C between 1 March and 1 May appear biologically important.
- Jan. models performed poorly in years with warm Jan. temperatures, potentially due to diapause (Hanson et al. 2013).
- Inconsistent calculation of simple degree-days may also explain why previous researchers previously noticed poorer predictions with the Ahmad model (McMaster & Wilhelm 1997).
- We recommend a simple degree-day model beginning 1 March while using a lower threshold of 3.3 °C, an upper threshold of 23.9 °C, and a target of 1,432 degree-days °C (2,577 °F) to predict 25% flight.
- This model should be more accessible to growers compared to more complex calculations (e.g., the sine-wave method).

References

- Ahmad 1979. Comparison of heat unit accumulation methods for predicting european corn borer and western bean cutworm moth Flights. [Thesis]. Lincoln, NE. University of Nebraska.
- Allen 1976. A modified sine wave method for calculating degree days. Environ. Entomol. 5:388-396.
- Hanson et al. 2013. Supercooling point of western bean cutworm (Lepidoptera: Noctuidae) collected in eastern Nebraska. Great Lakes Entomologist 46: 216-224.
- Hanson et al. 2016. Degree-day prediction models for the flight phenology of western bean cutworm (Lepidoptera: Noctuidae) assessed with the concordance correlation coefficient. J. Econ. Entomol. 108: 1728–1738.
- Michel et al. 2010. Ecology and management of the western bean cutworm (Lepidoptera: Noctuidae) in corn and dry beans. J. Integr. Pest Manag. 1.1 A1-A10.
- Liao 2003. An improved concordance correlation coefficient. Pharm. Stat. 2: 253–261
- McMaster and Wilhelm. 1997. Growing degree days: One equation, two interpretations. Agric. For. Meteorol. 87: 291–300.