Coupling Insect Pest Phenology Model into CropSyst: Cereal Leaf Beetle and Wheat Yield

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Introduction

Cropping system models used as a decision support tool to predict crop growth and yield under different soil, climate and management scenarios, are most often limited by a lack of incorporated constraints from pests, diseases and weeds). Coupling cropping system models with temperature-dependent process based pest modules can help explain the gap between potential and actual yield and evaluate global warming scenarios. Here we present results for winter wheat obtained by a version of the CropSyst model (Stöckle et al., 1994) that incorporates population dynamics and daily feeding injury to the crop caused by cereal leaf beetle (CLB), *Oulema melanopus* (L.) (Coleoptera: Chrysomelidae).

CLB as Pest of Winter Wheat: The CLB (Fig. 1), a native of Eurasia, is often a devastative foliage feeder pest of wheat in North America (Haynes and Gage 1981), especially in the PNW (Buntin et al., 2004). One larva per stem causes 5.9% -12.65% yield loss (Buntin et al., 2004). Although economic injury levels and phenological models have been developed for CLB (Ruesink, 1972), there has been no attempt to incorporate CLB phenology, feeding behavior and crop growth into coupled, predictive models (Boote et al., 1983). Such models can help anticipate responses of the system to changing climatic conditions.

Objectives

1.Develop and parameterize a phenology and feeding dynamics model for CLB on winter wheat and couple the output to CropSyst.
2. Illustrate the capabilities of the coupled model by simulating wheat yield loss by all four larval instars at below or above economic threshold levels (ETL) of CLB infestation for select locations in Washington State.

Methods

Weather: Data for 2004-2005 at Pullman (high rainfall, >20 inches per year) and Lind (low rainfall, 9-14 inches/year) in Washington were taken from Agweathernet (http://weather.wsu.edu/awn.php). A Single-Sine approach was used to calculate cumulative degree days using a base temperature for CLB of 9 °C (48.2 °F).

CLB phenology: Model was parameterized with daily reproduction, development and mortality rates for CLB estimated from published research (Guppy & Harcourt, 1978; Table 1). The corresponding temperature-controlled experimental data to estimate feeding rates (Table 1) were generated in our lab. Statistical freeware R 3.1 was used for estimation of parameters.

Wheat Yield: Simulated dry grain yield for Pullman and Lind in 2004-05 were 5.6t and 1.5t/ ha, respectively. We simulate and compare the wheat yields for two study locations with contrasting precipitation, at temperatures set to +1, +2, and + 3 °C above baseline and at varying initial spring female adult densities of 8,16, 24 and 32 per square meter ground area. Yield loss is computed relative to the yield without infestation at corresponding temperature.

Figure 1: CLB Adults, Larva and Skeletonized Leaf (Courtesy: N. Foote)

Table 1: Methodology for stage specific parameter estimation

Parameter (Day^{-1})	Estimation Method
Oviposition Rate (females)	0.183 per degree day above base 48.2° F
Developmental Rate Egg, Larva I, II, III and IV, Pupa	Sharpe-Schoolfield-Ikemoto model (OptimSSI package in R 3.1)
Mortality Rate Pre-season (Spring) Adults	0.2% and 0.4% per degree day above base 48.2° F before and after larval feeding begins, respectively
Egg and Larva I	Second order exponential polynomial
Larva II, III and IV	Linear model
Pupa	Segmented Linear model
Post-season (Summer) Adults	0.05% per degree day above base 48.2° F
Feeding Rate Larva I, II, III and IV	Second order exponential polynomial

Results: Simulated Phenology of CLB

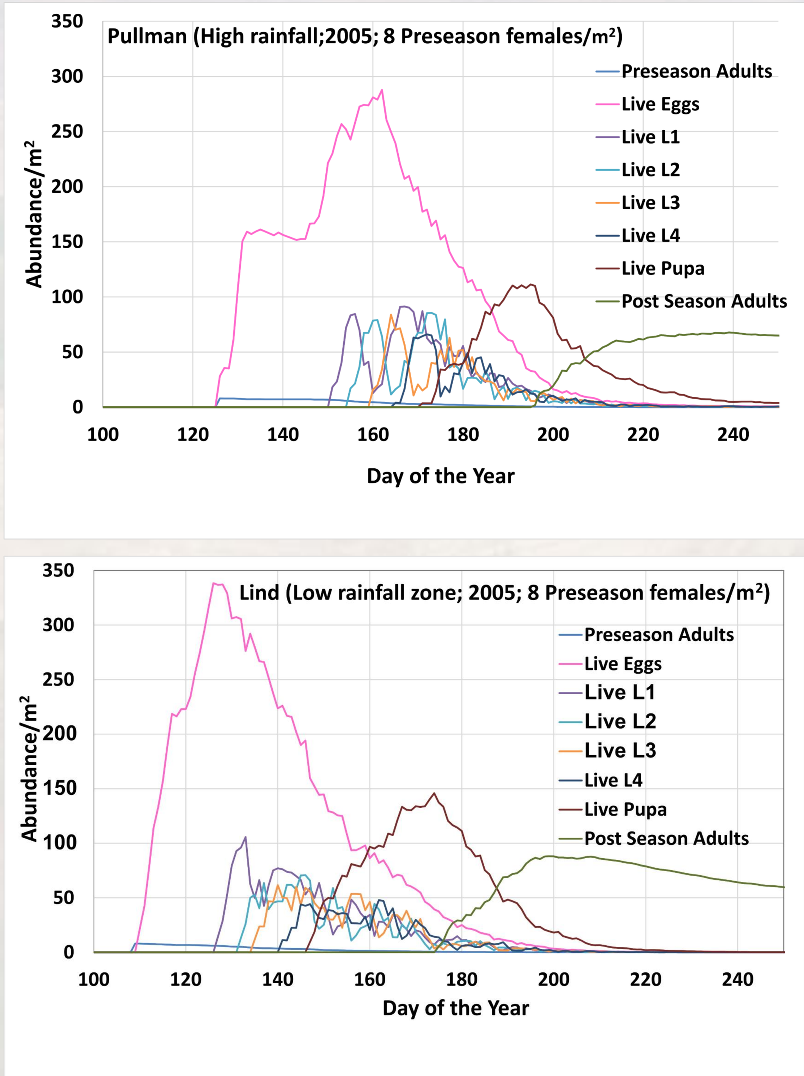

Figure 2: Phenology of CLB at Pullman and Lind

Results: CLB Larval Defoliation

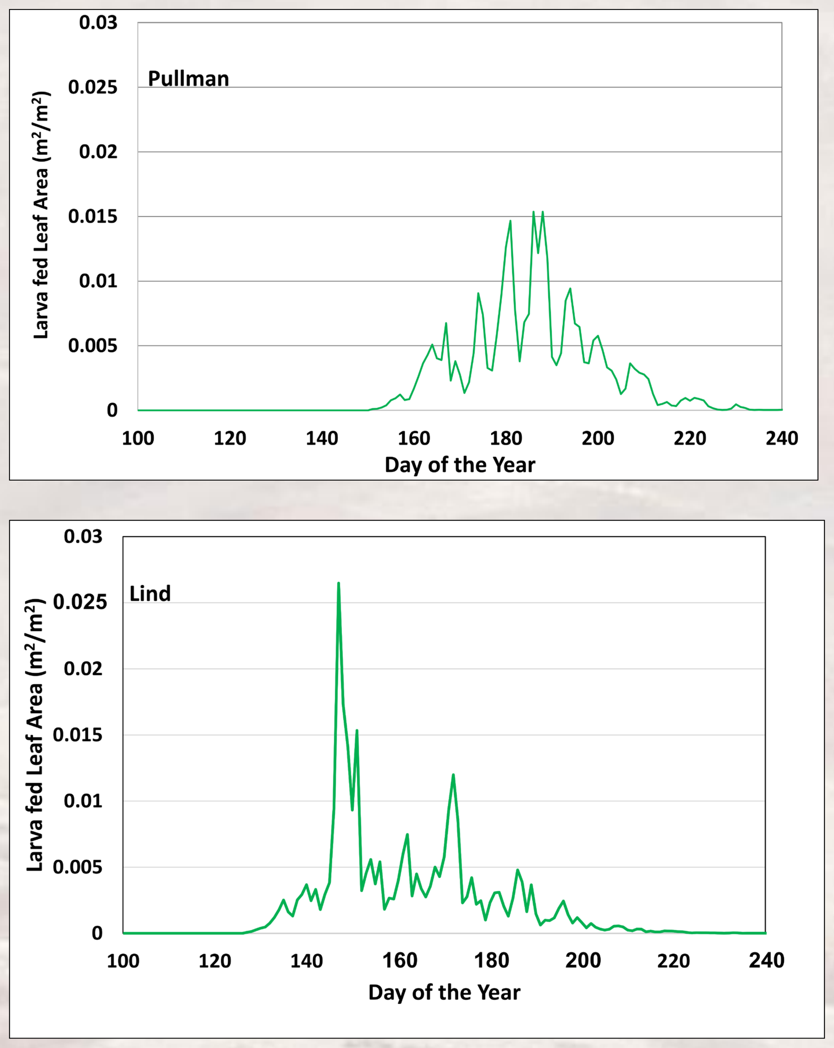

Figure 3: Simulated leaf area fed (sq. m) by all four instars in 2004-2005 at Pullman and Lind in a square meter area

Results: Defoliation and Yield Loss

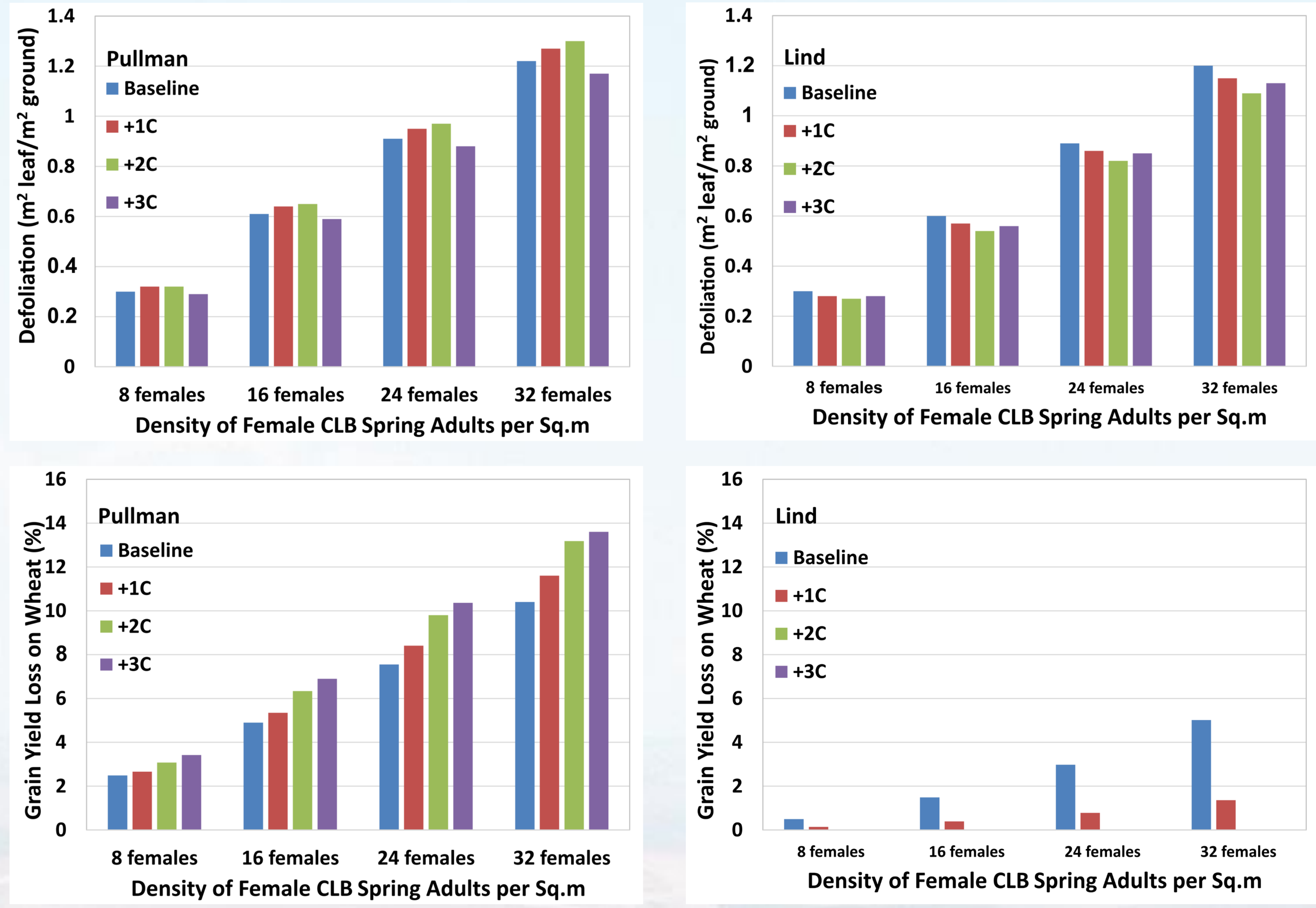

Figure 4: CLB defoliation and resultant yield loss

Summary of Results:

Defoliation and a relative yield loss increased linearly with CLB density at both the Lind and Pullman locations. At baseline temperatures, defoliation trends were similar but with increasing temperatures, changes in defoliation and relative yield loss differed substantially between the two locations.

Pullman: Both defoliation and relative yield loss increased with increasing temperature above the baseline up to +2°C. At +3°C defoliation decreased. Indeed, the amount of defoliation depends on the balance between defoliation intensity (increases with temperature) and defoliation duration (decreases with temperature).

Lind: Defoliation remained relatively unchanged or declined with increasing temperature, resulting from similar dynamics explained for Pullman (temperatures at Lind are greater than at Pullman). At baseline temperatures, yield loss was lower than at Pullman and it declined substantially with temperatures above baseline, becoming negligible above +2°C. At this location the crop attained full canopy before the majority of CLB feeding occurred. In addition, defoliation was of no significance because severe water stress reduced growth to near zero after full canopy and grain yield depended mostly on translocation of carbohydrates produced before grain filling.

Implications: In this example, the wheat-pest complex at two locations approximately 100km apart respond differently to the same temperature deltas. The result illustrates the potential of coupled process-based models for anticipating production system responses to climate change.

Limitations, Future Work:

- Although the estimates are consistent with some reported values (Buntin et al. 2004, Evans et al 2014), further validation is needed.
- The model could be augmented with variable seasonal and overwintering CLB mortality (Helgesen & Haynes, 1972; Maiorano et al., 2014), and the effects of the larval parasitoid, *Tetrastichus julis* (Walker).
- The model can now be extended to generate projections across the REACCH study region using gridded daily historical weather data and projections based on emission scenario (Abatzoglou 2013).

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