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Phenology maps for leafy spurge biological control agents: Development and application in the U.S.

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Five species of *Aphthona* flea beetles (Coleoptera: Chrysomelidae) and the gall midge *Spurgia esulae* (Diptera: Cecidomyiidae) are among the insects introduced into the U.S. as classical biological control agents of leafy spurge (*Euphorbia esula*). Nonlinear models describing the seasonal occurrence of adult *Aphthona* spp. and *S. esulae* life stages were developed using data from two Montana sites (1993-1995) and one Montana site (1992-1995), respectively. Models for all species exhibited r^2 values exceeding 0.60. Peak occurrence of adults of *A. nigriscutis*, *A. czwalinae*/*A. lacertosa* (mixed populations), *A. cyparissiae*, and *A. flava* occurred at 1230, 1320, 1565 and 1580 degree-days accumulated from January 1, respectively ($>0^\circ\text{C}$). The occurrence first-generation *S. esulae* pupae (the optimal life stage for collection) peaked at 990 accumulated degree-days $>0^\circ\text{C}$. The mean calendar dates by which these degree-day values accumulated were calculated for nearly 300 weather stations in the central and western U.S., using temperature data sets that spanned 40 to 110 years. These data were then used to recommend sampling dates (i.e. scheduled to anticipated peak adult abundance) in the various U.S. states. Contour maps were prepared that displayed predicted *Aphthona* spp. sampling or collection dates in the western and midwestern U.S. (based on anticipated peak adult abundance), over weekly intervals ranging from May 15 to August 28 depending on species and location. A similar contour map was prepared for *S. esulae* collections, based on peak first-generation pupae; weekly intervals ranged from April 24 to July 17. Phenological events generally happened earliest in New Mexico, southern Utah and southern Colorado and latest in higher-elevation portions of western Wyoming and eastern Idaho. Additional applications for phenology maps include determining relationships between agent populations and length of growing season, and the general determination of “bioclimatic suitability” of different areas of the U.S. for a given agent.