Developmental Database for Phenology Models: Related Insect and Mite Species Have Similar Thermal Requirements

VOJTĚCH JAROŠÍK,[1,2,3] ALOIS HONĚK,[4] ROGER D. MAGAREY,[5] AND JIŘÍ SKUHROVEC[4]

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ABSTRACT Two values of thermal requirements, the lower developmental threshold (LDT), that is, the temperature at which development ceases, and the sum of effective temperatures, that is, day degrees above the LDT control the development of ectotherms and are used in phenology models to predict time at which the development of individual stages of a species will be completed. To assist in the rapid development of phenology models, we merged a previously published database of thermal requirements for insects, gathered by online search in CAB Abstracts, with independently collected data for insects and mites from original studies. The merged database comprises developmental times at various constant temperatures on 1,054 insect and mite species, many of them in several populations, mostly pests and their natural enemies, from all over the world. We show that closely related species share similar thermal requirements and therefore, for a species with unknown thermal requirements, the value of LDT and sum of effective temperatures of its most related species from the database can be used.

KEY WORDS lower developmental threshold, base temperature, sum of effective temperatures, day degrees, rate of development

While birds and mammals produce metabolic heat, enabling them to grow and develop in a range of ambient temperatures by burning food, ectotherm organisms, that is, plants, fungi, bacteria, virus and virus-like organism, protists, and all animals except birds and mammals, rely on external sources of heat for their development. Because ectotherms require a certain combination of time and temperature, their development is a function of a given temperature and time over which it is acting. This time, called thermal or physiological, is the basis of phenology models that use two values of thermal requirements: 1) lower developmental threshold (LDT), that is, the temperature at which development ceases (also called based developmental temperature); and 2) the sum of effective temperatures (SET), that is, day degrees (DD) above the LDT necessary for a completion of a developmental stage (Ludwig 1928). A heat accumulation of DD above LDT enables prediction of the time at which the development of individual stages of a species will be completed. In insect and mites, the thermal accumulation is usually modeled by daily maximum and minimum temperatures, assuming the sine curve as an approximation of the diurnal temperature curve (Baskerville and Emin 1969, Allen 1976).

To create a phenology model of a species, it is necessary to obtain data on the thermal requirement of the modeled species. This requires a literature search for published thermal requirements, or, alternatively, because the application of the thermal requirements is often limited by the lack of available data, new laboratory experiments.

In literature, the base developmental temperatures (LDTs) are given separately for each developmental stage within a population of a species. This is so because, until recently, it was considered that within a species, each developmental stage has its own, specific lower developmental threshold. This understanding has changed when Jarošík et al. (2002) showed that the proportion of the developmental time, spent in individual developmental stages of a species, does not change with temperature. This means that within a population of a species, the LDT remains the same for all developmental stages. Consequently, when LDT is known only for any one of developmental stages of a species, this LDT can be used for all developmental stages of the species.

The existence of a common LDT within a species, called rate isomorphy (van Rijn et al. 1995), was first tested on insect and mites, using data on the duration of nondormant development for 426 populations of 349 species (Jarošík et al. 2002). Later it was shown that rate isomorphy occurs in all ectotherm animals (Jarošík et al. 2004), and different methods to tests for

[1] Charles University, Faculty of Science, Department of Ecology, Viničná 7, 128 43 Prague 2, Czech Republic.
[2] Institute of Botany ASCR, CZ-252 43 Průhonice, Czech Republic.
[3] Corresponding author, e-mail: jarosik@cesnet.cz.
[4] Crop Research Institute, Drnovská 507, CZ 161 06 Prague 6–Ruzyně, Czech Republic.
[5] Center for Integrated Pest Management, North Carolina State University, 1730 Varsity Drive, Suite 110 Raleigh, NC 27606.