# Short life cycles in insects and mites[1]

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**Abstract**—Under favourable conditions some species of insects and mites complete development very quickly. This paper considers species with a mean minimum generation time of 15 days or less and tabulates developmental data for many sample species. Such species belong chiefly to a limited number of taxa of small size, notably aphids and several families of mites and parasitoid Hymenoptera. Characteristics of these taxa are reviewed. Even in families containing many species with rapid life cycles, normally many other species lack such rapid development. Very short life cycles depend on phylogeny, strain, rapid development in all stages, small size, rich food, and other habitat features including high temperatures. Within this framework, life cycles are accelerated by reducing elements requiring the investment of resources (size, fecundity, longevity, structural complexity), eliminating instars and even life stages, accelerating development (through lower requirements especially of heat, heat gain by adaptations such as basking, and rapid reproduction), and choosing the most suitable habitats and microhabitats from those available. Mean minimum generation times in insects and mites with coincident adaptations of this sort can be as short as 4 days. Notwithstanding the advantages of rapid development in maximizing the intrinsic rate of natural increase (and hence fitness), most species cannot achieve the highest rates of development. They are constrained not only by resources and intrinsic physiological or phylogenetic patterns but also by variability of conditions and seasonality that can be survived only by interpolating delays or resistant stages.

**Résumé**—Sous des conditions favorables, certains insectes et acariens complètent leur développement très rapidement. Il est question ici d'espèces qui ont une durée de génération minimale moyenne de 15 jours ou moins et on y trouve des compilations des données de développement pour plusieurs espèces choisies. La plupart de ces espèces appartiennent à un nombre réduit de taxons de petite taille corporelle, particulièrement des pucerons et plusieurs familles d'acariens et d'hyménoptères parasitoïdes. Les caractéristiques de ces taxons sont passés en revue. Même dans les familles qui contiennent plusieurs espèces à cycle biologique rapide, il y a normalement beaucoup d'autres espèces qui n'ont pas ce développement rapide. Les cycles biologiques très courts dépendent de la phylogénie, de la race, d'un développement rapide à tous les stades, d'une taille réduite, d'une nourriture riche et d'autres caractéristiques du milieu, dont des températures élevées. Dans ce cadre, l'accélération du cycle se fait par la réduction des éléments qui requièrent un investissement de ressources (taille, fécondité, longévité, complexité structurelle), l'élimination de stades ou mêmes d'étapes du cycle, l'accélération du développement (par des exigences réduites particulièrement de chaleur, l'acquisition de chaleur par des comportements tels que l'exposition au soleil et la reproduction rapide) et le choix des habitats et des microhabitats les plus appropriés parmi ceux qui sont disponibles. Les durées de génération minimales moyennes chez les insectes et les acariens qui possèdent des combinaisons d'adaptations de ce type peuvent être aussi courtes que 4 jours. Malgré les avantages du développement rapide pour augmenter le taux intrinsèque d'accroissement naturel (et ainsi la fitness), la plupart des espèces n'arrivent pas à atteindre les taux les plus rapides. Elles en sont empêchées non seulement par le manque de ressources et par leurs taux physiologiques et phylogénétiques intrinsèques, mais aussi par la variabilité des conditions et par les variations saisonnières qui exigent des animaux l'insertion dans leur cycle de délais ou de stades résistants pour assurer leur survie.

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## Introduction

Some arthropod species develop rapidly, especially in certain life stages. For example, many entomologists have commented on the fact that in several families of Diptera the larvae ("maggots") grow conspicuously fast (*cf.* Levot *et al.* 1979). However, extremely rapid development in all stages from egg to adult is not especially common, and many earlier studies of life cycles have instead emphasized long life cycles (Danks 1992) and developmental delays such as diapause (*e.g.*, Danks 1987). This paper explores the features of species in which some individuals can complete a whole life cycle in 15 d or less under suitable conditions. Characteristics of such species can be related to intrinsic features and external conditions, providing wider lessons about the nature of habitats and the constraints on development.

## Methods

Information on species with short life cycles was obtained by a review of publications on the life cycles of arthropod species in the international entomological and acarological literature; that review included the detailed examination of each volume from 1960 onwards of about 20 journals selected because they commonly contain papers on insect and mite development. Data that document short life cycles, as well as information on intrinsic or environmental correlates and on mechanisms by which these life cycles are achieved, have three major weaknesses. First, many publications present data on only part and not the whole of the life cycle, making it impossible to put the data reported to full use for the current purpose. For example, a majority of publications on insect development give the duration of immature development but provide insufficient information on adults to determine the generation time. In some instances the difficulty is compounded because larval-pupal (or larval) development has been examined in detail, but there is no corresponding information on eggs (or on eggs and pupae). Other publications provide detailed adult reproductive statistics, especially the duration of oviposition, but give insufficient data on preoviposition intervals. Moreover, because strains and food conditions in experiments done at different times usually are not the same, data on the same species in different studies are not equivalent. For example, in different studies cited by Morgan *et al.* (2001: Table 5), minimum generation time of the aphid *Acyrthosiphon pisum* (Harris) at 20 °C varied between 6.4 and 9.9 d.

Second, there are biases as to the species and conditions examined, so that the relative occurrence of reports on fast development does not fully reflect the real patterns among taxa. For example, an emphasis on plant-feeding pests in the literature somewhat favours species with relatively rapid development in the larval stage because this feature tends to increase the potential for crop damage. Another emphasis is on potential agents for biological control, including predators and parasitoids with relatively rapid development that favours their ability to constrain prey or host populations.

Third, many published data on development suffer from weaknesses of experimental design or analysis (Danks 2000). For example, measures from adults kept under poor conditions (*e.g.*, inadequate food for maintenance or egg development, or inadequate light for activity) give no meaningful measures of preoviposition intervals or patterns of oviposition. Even measuring short life cycles accurately presents several experimental difficulties. Rapid stages are best recorded using intervals for observation of less than a day, because otherwise means will be inaccurate and the variance of the results will be artificially reduced (references in Danks 2000, p. 296). A major difficulty, especially with recent publications, is that instead of basic information, only highly transformed statistics or graphical representations are presented; these may serve the purpose of the individual paper, such as mathematical modelling, but are not more widely useful (Danks 2000).

Consequently, despite the many published studies of insect and mite development, it is not feasible to tabulate a wide range of life-cycle statistics for a diversity of rapidly developing species. Instead, I document the reported values of four informative and relatively widely available measures. (1) **Minimum generation time** (labelled ***G***, the commonly used symbol for this statistic, in tables in this paper) is the mean interval from oviposition (or larviposition) to the *first* progeny of the next generation (*cf.* Abou-Setta and Childers 1991). This interval is equivalent to the mean immature development time plus the mean preoviposition interval. (2) **Observed generation time** (***O***) is the recorded interval from oviposition to the *mean* progeny of the next generation. (3) **Calculated generation time** (***T***) is the calculated demographic statistic

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for mean generation time (Birch 1948; Carey 1993). It is similar to the observed generation time but may differ somewhat depending on the way in which data are recorded and the method of calculation. (4) **Immature development time** (***D***) is the mean duration from egg deposition to adult emergence (or larviposition to the adult moult). When available, the duration is that of the development of females, on which the generation time depends. This sort of information is readily available and can supplement information for taxa in which generation time has been reported elsewhere.

Generation times or developmental intervals estimated from published information (rather than cited directly) are shown in parentheses in tabulations here. For example, in some reports relevant information could be estimated from methodological comments, such as the age of adults when the next batch of eggs was obtained, from graphical summaries of the pattern of oviposition, or from other quantitative information.

Developmental and generation times of a given species may depend on the strain and the conditions (temperature, food, humidity, density, and so on). For the main purpose of this paper, only the fastest times given in any report are listed. However, in some species a very short minimum generation time has been reported under conditions that are generally unsuitable (such as high temperatures), giving extremely low survival, fecundity, or rates of natural increase ($r_m$). For example, egg to adult development of the mosquito *Culex annulirostris* Skuse takes 8.3 d at 35 °C and 12.5 d at 30 °C, but survival at the higher temperature is only 22%, compared with 65% at the lower temperature (Mottram *et al.* 1986). Because the gonotrophic cycle lasts a minimum of 4 d in this species, life cycles of less than 15 d are possible but not optimal. The mean generation time of the aphid *Brachycaudus rumexicolens* (Patch) is only 5.6 d at 30 °C (Scott and Yeoh 1999), compared with 7.2 d at 27.9 °C, but at the higher temperature survival and reproduction are so low that $r_m$ is negative. Such data for very rapid development were rejected if the life cycle was clearly unsuccessful under the given conditions and data were available for less extreme conditions.

Some comparative remarks are made here about species with longer life cycles. These remarks are based on many reports in the literature (consulted whilst compiling data on short life cycles) but the reports generally have not been cited in order to avoid adding hundreds of additional references peripheral to the main theme.

## Taxa with very short life cycles

Taxa characterized by species with very short life cycles are summarized here. Normally other species in the same taxa (not tabulated here) have life cycles that are longer even under the most favourable conditions. Such differences among species are especially noticeable in more diverse taxa (*e.g.*, Tetranychidae, Braconidae). Typically, the differences accord with ecological or other requirements discussed in later sections.

### Acari

Most mites are small and in certain families many species, but by no means all, develop relatively rapidly. However, other large groups are characterized by slow development: ticks (Ixodida), in which delays may also be associated with host finding; soil mites (Oribatida), which have unusually slow development (*e.g.*, Woodring and Cook 1962; Jalil 1972; Norton 1994); and many water mites (Hydrachnidia), which have only one generation per year (Proctor and Pritchard 1990).

#### *Mesostigmata*

Many species of Phytoseiidae have been reared in the laboratory as potential predators of pest mites and small insects or their eggs. The family is characterized by rapid development without elimination of instars. Many species have minimum generation times of less than 10 d, and even mean generation times of less than 15 d are not uncommon (Table 1; Jeppson *et al.* 1975, p. 79; see also Sabelis 1991; additional data for immature development only, *e.g.*, Takahashi and Chant 1992, are not included in the Table).

Records of rapid development are available for a few other families of mites in the same suborder (Table 2). Most of the species are relatively small and most of them are predatory. Egg to adult development is extremely rapid in some species, for example lasting only 1.5 d in some species of *Macrocheles* (Table 2; Cicolani 1983). Records for species with egg to adult development times of less than 10 d, in addition to those in Table 2, were listed by Walter and Ikonen (1989) for Digamasellidae (8–9 d) and

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**Table 1.** Sample records of short life cycles in Phytoseiidae, listed with the shortest records first.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Neoseiulus womersleyi* (Schicha) [*Amblyseius*] | 4.0 | | 6.9 | 2.0 | 33 | Lee and Ahn 2000 |
| *Neoseiulus fallacis* (Garman) [*Amblyseius*] | 4.0 | | | 3.3 | 32 | Smith and Newsom 1970 |
| | 4.4 | | | 3.5 | 26.4 | Ball 1980 |
| | 6.6 | (13) | | 4.1 | 26 | Boyne and Hain 1983*b* |
| | | | | 4.6 | 26 | Kramer and Hain 1989 |
| *Neoseiulus bibens* (Blommers) [*Amblyseius*] | 4.7 | | | (3.7) | 31 | Blommers 1976 |
| | 5.3 | | 9.1 | 4.1 | 29 | |
| *Mesoseiulus longipes* (Evans) [*Phytoseiulus*] | 5.0 | 7.8 | | 3.9 | 35 | Badii and McMurtry 1984 |
| *Euseius citrifolius* Denmark and Muma [*Amblyseius*] | (5.3) | (10.6) | | 3.6 | 30 | de Moraes and McMurtry 1981 |
| *Phytoseiulus macropilis* (Banks) | 5.4 | | 8.8 | 4.2 | 28 | Ali 1998 |
| | 5.5 | | | 4.2 | 26 | Prasad 1967 |
| | 7.5 | | | 6.0 | 26.4 | Ball 1980 |
| | 8.9 | | | 6.8 | 23–25 | Kropczynska *et al.* 1988 |
| *Neoseiulus longispinosus* (Evans) [*Amblyseius*] | | | 9.7 | 4.1 | 27 | Mallik and ChannaBasavanna 1983 |
| | 5.5 | | 10.4 | 4.4 | 25 | Saitô and Mori 1981 |
| | 8.4 | | | 4.8 | 28 | Thongtab *et al.* 2001 |
| *Galendromus occidentalis* (Nesbitt) [*Typhlodromus*, *Metaseiulus*] | 5.5 | (10) | | 4.5 | 35, 30 | Pruszynski and Cone 1973 |
| | 5.9 | | 10.2 | | 32 | Tanigoshi *et al.* 1975*b* |
| | 7.6 | | | 6.3 | 23.9 | Lee and Davis 1968 |
| | 8.1 | | | 6.4 | 25 | Badii and McMurtry 1984 |
| *Galendromus longipilus* (Nesbitt) | 5.5 | | | 3.9 | 26.4 | Ball 1980 |
| *Euseius mesembrinus* (Dean) [*Amblyseius*] | (5.5) | | 9.6 | | 26 | Abou-Setta and Childers 1989 |
| *Typhlodromips swirskii* (Athias-Henriot) [*Amblyseius*] | 5.5 | 17.0 | | 3.8 | 26 | El-Laithy and Fouly 1992 |
| | 7.5 | | | 5.7 | 27 | Momen and El-Saway 1993 |
| | 9.2 | | 19.7 | 8.0 | 29 | Abou-Awad *et al.* 1999*a* |
| *Euseius concordis* (Chant) | 5.8 | | | 5.0 | 25 | de Moraes and Lima 1983 |
| *Typhlodromalus lailae* (Shicha) | (6) | | 8 | | 25 | Steiner *et al.* 2003*b* |
| *Euseius finlandicus* Oudemans [*Amblyseius*] | (6) | | 15.9 | 4.3 | 32 | Broufas and Koveos 2001 |
| | (7.4) | | 14.7 | 6.4 | 20 | Broufas and Koveos 2000 |
| | 9.8 | | | 7.8 | 23–25 | Kropczynska *et al.* 1988 |

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**Table 1** (*continued*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Euseius stipulatus* (Athias-Henriot) | 5.8 | | 9.7 | 5.5 | 32 | Ferragut *et al.* 1987 |
| *Galendromus helveolus* (Chant) | 6.1 | | 10.2 | 4.6 | 30 | Caceres and Childers 1991 |
| *Euseius alatus* DeLeon | 6.3 | | 14.1 | 4.5 | 25 | Reis and Alves 1997 |
| *Amblyseius deleoni* Muma and Denmark | 6.3 | | 11.25 | 4.9 | 25 | Saitô and Mori 1981 |
| *Cydnoseius africanus* (Yousef) [*Typhlodromus*] | 6.7 | | | 5.2 | 25 | Yousef 1981 |
| *Phytoseiulus persimilis* Athias-Henriot | | | | 4.0 | 25 | Toyoshima and Amano 1999 |
| | 6.8 | | | 5.1 | 25 | Badii and McMurtry 1984 |
| | 6.9 | (15?) | | 5.4 | 25 | Takafuji and Chant 1976 |
| | 7.5 | (15) | | 6.1 | 25 | Amano and Chant 1977 |
| | 10.4 | | 17.3 | 7.4 | ~20.3 | Laing 1968 |
| *Neoseiulus idaeus* Denmark and Muma [*Amblyseius*] | 7.0 | | 17.0 | 4.6 | 25 | Dinh *et al.* 1988 |
| *Typhlodromips montdorensis* (Schicha) | (7) | | 9.3 | | 25 | Steiner *et al.* 2003*a* |
| *Typhlodromus phialatus* Athias-Henriot | 7.4 | | 13.6 | | 32 | Ferragut *et al.* 1987 |
| *Phytoseius plumifer* (Canestrini and Fanzago) | 7.5 | | | 5.3 | 29.5 | Zaher *et al.* 1969 |
| *Neoseiulus anonymus* (Chant and Baker) [*Amblyseius*] | 7.6 | | 17.8 | 4.9 | 25 | Dinh *et al.* 1988 |
| *Euseius scutalis* (Athias-Henriot) [*Amblyseius*] | 7.8 | | 14.7 | 6.1 | 26 | El-Laithy and Fouly 1992 |
| *Neoseiulus paraki* (Ehara) [*Amblyseius*] | 8.0 | | 13.5 | 5.9 | 25 | Saitô and Mori 1981 |
| *Iphiseius degenerans* (Berlese) [*Amblyseius*] | 8.0 | (?19) | | 5.7 | 25 | Takafuji and Chant 1976 |
| *Typhlodromalus peregrinus* (Muma) [*Typhlodromus*] | 8.1 | | 14.4 | 6.3 | 26 | Fouly *et al.* 1995 |
| *Neoseiulus umbraticus* (Chant) [*Amblyseius*] | (8.4) | (16.4) | | 6.4 | 25–26 | Knisley and Swift 1971 |
| *Typhlodromalus limonicus* (Garman and McGregor) [*Amblyseius*] | 8.5 | | | 6 | 22.2 | McMurtry and Scriven 1965 |
| *Neoseiulus masiaka* (Blommers and Chazeau) [*Amblyseius*] | 8.7 | | | 6.7 | 25 | Blommers 1974 |
| *Euseius hibisci* (Chant) [*Amblyseius*] | 8.8 | (17) | | 6.7 | 25.5–26.7 | Tanigoshi *et al.* 1983 |
| | | | 8.8 | 4.6 | 35 | Tanigoshi *et al.* 1981 |
| *Amblyseius largoensis* (Muma) | | | 9.0 | 3.2 | 35 | Yue and Tsai 1996 |
| *Amblyseius badryi* Yousef and El-Brollosy | 9.0 | | 17.2 | 7.4 | 27 | Abou-Awad *et al.* 1998 |
| *Euseius metwallyi* Basha, Yousef and Mostafa | 9.1 | | | 7.3 | 27.1 | Basha *et al.* 2002 |
| *Bawus talbii* (Athias-Henriot) [*Typhlodromus*] | 9.2 | | 17.3 | 6.7 | 27 | Camporese and Duso 1995 |
| *Orientiseius rickeri* (Chant) [*Typhlodromus*] | 9.4 | | | 6.4 | 22.2 | McMurtry and Scriven 1964 |
| *Amblydromella caudiglans* (Shuster) [*Typhlodromus*] | 9.5 | | | 6.7 | 24.4–25 | Putman 1962 |

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**Table 1** (*concluded*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Amblyseius andersoni* (Chant) | 9.6 | (18) | | 7.4 | 25 | Amano and Chant 1977 |
| *Euseius gossipi* (El-badry) [*Amblyseius*] | 9.8 | | | 6.5 | 30.6 | Yousef *et al.* 1982*b* |
| *Typhlodromus exhilaratus* Ragusa | (9.9) | | | 7.4 | 26 | Castagnoli and Liguori 1986 |
| | 10.0 | 16.7 | | 7.5 | 25 | Castagnoli *et al.* 1989 |
| *Typhlodromips sessor* (DeLeon) | 9.9 | | | 7.6 | 25 | Sciarappa and Swift 1977 |
| *Paraseiulus soleiger* (Ribaga) [*Phytoseius*] | 9.9 | | | 7.5 | 23–25 | Kropczynska *et al.* 1988 |
| *Euseius finlandicus* (Oudemans) [*Amblyseius*] | 10.0 | | | 7.8 | 23–25 | Kropczynska *et al.* 1988 |
| *Proprioseiopsis temperellus* (Denmark and Muma) | 10.4 | | | 5.7 | 26.4 | Ball 1980 |
| *Kampimodromus aberrans* (Oudemans) [*Amblyseius*] | 10.5 | | | 8.3 | 23–25 | Kropczynska *et al.* 1988 |
| *Amblydromella kettanehi* (Dosse) | 11 | | | 5.5 | 23 | Arbabi and Baradaran 2001 |
| *Neoseiulus barkeri* Hughes [*Amblyseius*] | 11.3 | | | 8.45 | 25 | Momen 1995 |
| *Phytoseius hawaiiensis* Prasad | 11.6 | | | 6.9 | 24 | Sanderson and McMurtry 1984 |
| *Typhlodromus pyri* Scheuten | 12.4 | | | 9.6 | 24 | Kropczynska *et al.* 1988 |
| | 15 | | | 10 | 18.3 | Herbert 1961 |

**Note:** *G*, minimum generation time; *O*, observed generation time; *T*, calculated generation time; *D*, immature development time. All values are mean durations, shown in days; estimated values are shown in parentheses. For further details see Methods. Taxonomy for this family is according to de Moraes *et al.* (1986); other names used in the cited references are shown in brackets.

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**Table 2.** Sample records of short life cycles in other mesostigmatic mites.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| **Digamasellidae** | | | | | | |
| *Dendrolaelaps neodisetus* (Hurlbutt) | 9.4 | | | 7.9 | 25 | Kinn 1984 |
| **Laelapidae** | | | | | | |
| *Haemolaelaps centrocarpus* Berlese | 14.8 | | | 11.8 | 27 | Furman 1966 |
| **Macrochelidae** | | | | | | |
| *Macrocheles muscaedomesticae* (Scopoli) | | | 4.5 | 1.8 | 30 | Filipponi *et al.* 1971*a*; Cicolani 1979 |
| | 4.6 | | | 2.3 | 26.7 | Wade and Rodriguez 1961 |
| | 5.1 | | | 2.9 | 30 | Ho 1989 |
| *Macrocheles matrius* (Hull) | | | 4.5 | 2.1 | 34 | Filipponi and Cicolani 1974; Cicolani 1979 |
| | | | | 2.2 | 34 | Cicolani 1978 |
| | 4.9 | | | 3.4 | 30 | Soliman *et al.* 1978 |
| *Macrocheles subbadius* (Berlese) | | | 4.9 | 1.6 | 31 | Cicolani *et al.* 1977; Cicolani 1979 |
| *Macrocheles robustulus* (Berlese) | | | 5.2 | 1.4 | 3.3 | Filipponi and Mosna 1968; Cicolani 1979 |
| *Macrocheles perglaber* Filipponi and Peggazano | | | 5.6 | 1.8 | 34 | Filipponi and Petrelli 1969; Cicolani 1979 |
| *Macrocheles boudreauxi* Krantz | 6.3 | | | 4.2 | 20 | Kinn and Witcosky 1977 |
| *Macrocheles peniculatus* Berlese | | | 7.7 | 3.0 | 28 | Filipponi and Passariello 1969; Cicolani 1979 |
| *Macrocheles penicilliger* (Berlese) | | | 11.6 | 4.6 | 22–26 | Filipponi *et al.* 1971*b*; Cicolani 1979 |
| **Ascidae** | | | | | | |
| *Rhinoseius richardsoni* Hunter | 5–7 | | | | Field | Colwell 1973 |
| *Rhinoseius colwelli* Hunter | 5–7 | | | | Field | Colwell 1973 |
| *Blattisocius tarsalis* (Berlese) [*Melichares*] | 7.4 | (15) | | 5.9 | 27 | Haines 1981 |
| | 8.7 | | | 6.9 | 25 | Darst and King 1969 |
| | | | | 7.0 | 25 | Nielsen 2001 |
| *Arctoseius semiscissus* (Berlese) | (9) | | 13.85 | 7.85 | 20 | Rudzińska 1998 |
| *Lasioseius athiasae* Nawar and Nasr | | | 17.9 | 7.4 | 27 | Abou-Awad *et al.* 2001 |
| *Blattisocius dentriticus* (Berlese) [*Melichares*] | (14) | | | 10 | 22.2 | Rivard 1960 |
| **Hypoaspididae** | | | | | | |
| *Hypoaspis miles* Berlese | 14.2 | | 26.6 | 10.5 | 30 | Ydergaard *et al.* 1997 |
| **Pachylaelapidae** | | | | | | |
| *Zygoseius furciger* Berlese | | | | 4.5 | 25 | Walter and Proctor 1999, p. 49 |

**Note:** Conventions as in Table 1.

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Ascidae (5–9 d) and by Ruf (1996, Appendix) for Eviphidae (9 d), Ascidae (5–9 d), Laelapidae (5–9 d), and Parasitidae (6–8 d). These records suggest that other mesostigmatid mites will prove to have short life cycles.

### *Prostigmata*

Many species of Tetranychidae, small phytophagous species that are pests or potential pests on a wide range of plants, have been reared in the laboratory. A few species have minimum generation times below 10 d, and many more are below 15 d (Table 3).

There are relatively few observations for other families of prostigmatic mites (Table 4). However, rapid development is known in various families. For example, scattered records are available for fungus-feeding mites in the families Pygmephoridae and Tarsonemidae, for some species of tiny phytophagous mites of the family Eriophyidae, for insect egg parasitoids (*sensu* Lindquist 1983) of the families Pyemotidae and Acarophenacidae, for the tarsonemid genus *Iponemus*, and for other families. However, most other species of prostigmatic mites develop more slowly, including species in the subcohort Parasitengona (Wohltmann 2000: Table 5).

### *Astigmata (Acaridiae)*

This suborder includes many slow-moving and non-predatory mites, although many others are parasitic on birds and mammals. Acarids normally feed on fungi, and relatively short generation times are known in a range of species (Table 5; OConnor 1994). Some species in the family Histiostomatidae, which appear to be filter-feeders on microorganisms and live in many different habitats, also have rapid development (Table 5).

## Insecta

Very short generation times are confined to relatively few taxa of insects, and most species develop more slowly. For example, many species of Odonata are large and take several years to develop. Most Plecoptera live in very cool habitats and few species have more than one generation per year. Cockroaches have a reputation for rapid population growth, but developmental times of most species are not particularly short. Long life cycles are also prevalent in the major orders Coleoptera and Lepidoptera. Most of the species that develop very rapidly belong to relatively few families of Hemiptera, Diptera, and Hymenoptera.

### *Hemiptera*

Many species of aphids have minimum generation times of 10 d or less under suitable conditions and mean generation times that are only a few days longer (Table 6). Rapid larval development is followed by very short periods between adulthood and larviposition of the next generation. Most members of this family are adapted for rapid reproduction by apterous virginoparae on summer host plants. However, fundatrices, the initial generation in spring, may develop even faster than the virginoparae. For example, the minimum generation time of fundatrices of *Eulachnus agilis* (Kaltenbach) is only 11.5 d, compared with 13.3 d for virginoparae (Bliss and Kearby 1971).

Most other families of small phytophagous Homoptera have slower larval development than aphids and are not larviparous, so that generations normally take slightly more than 15 d even in the smallest and most rapidly developing species of families such as Aleyrodidae, Psyllidae, Cicadellidae, and Delphacidae (but see Patil *et al*. 1994). Many other species take longer.

Development of most Heteroptera is slower still, not only in blood-feeding species in families such as Reduviidae, but also in phytophagous and predatory species (*e.g.*, in the Pentatomidae). A generation can be completed in less than 20 d in a few small species of mirids and anthocorids, and some anthocorids, which are predators of other arthropods, have minimum generation times just below 15 d (Table 7).

### *Thysanoptera*

Most thrips are very small, normally less than 2 mm in length. Different species eat a variety of foods including fungi, plant tissues, pollen, and other invertebrates. Pest species in the largely phytophagous family Thripidae have been the most studied, and generation times of 12 to 15 d are not uncommon (Table 8). However, by no means all species are included, notably because egg development may take longer than larval development.

### *Coleoptera*

Very few beetles have short life cycles, and even in species with rapid immature development the reproductive period normally is prolonged, typically including both a long preoviposition

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**Table 3.** Sample records of short life cycles in Tetranychidae.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Oligonychus pratensis* (Banks) | | | | 4.9 | 36 | Perring *et al.* 1984*a* |
| | 5.6 | | 5.9 | 5.2 | 36 | Perring *et al.* 1984*b* |
| | 6.5 | | 10.6 | 6.0 | 31 | Congdon and Logan 1983 |
| | 7 | | | 6 | 24–41 | Tan and Ward 1977 |
| *Oligonychus indicus* (Hirst) | 5.7 | | | 5.15 | 30 | Gupta *et al.* 1975 |
| | 5.3 | | | 4.05 | 35 | |
| *Panonychus citri* (McGregor) | 6.0 | | | 4.6 | 25 | Ashihara 1987 |
| *Tetranychus urticae* Koch | 6.8 | | 13.2 | 6.1 | 29.4 | Carey and Bradley 1982 |
| | 7.1 | | | 6.1 | 35 | Pruszynski and Cone 1973 |
| | 7.3 | | | 6.7 | 26.4 | Ball 1980 |
| | (9.6) | | 13.6 | 7.6 | 27 | Shih *et al.* 1976 |
| | | | 13.8 | | | Feldmann 1981 |
| | | | 16.2 | 9.9 | 25 | Saitô 1979 |
| | 10.2 | | | 8.0 | 21 | Herbert 1981*b* |
| | (11.6) | | | | 25 | Krips *et al.* 1998 |
| | 15.1 | | 19.7 | 14.5 | 24 | Grissa-Lebdi *et al.* 2002 |
| | 19.0 | | 10.9 | 16.9 | ~20.3 | Laing 1969 |
| | | | 13.8 | | | Feldmann 1981 |
| | | | 17.2 | 7.4 | 30 | Bounfour and Tanigoshi 2001 |
| *Tetranychus pacificus* McGregor | 6.3 | | | | 30.2 | Oi *et al.* 1989 |
| | 7.1 | | 12.5 | 6.7 | 29.4 | Carey and Bradley 1982 |
| | 12.3 | (24?) | | 10.5 | 25 | Takafuji and Chant 1976 |
| *Tetranychus turkestani* (Ugarov and Nikolski) | 7.2 | | 12.55 | 6.4 | 29.4 | Carey and Bradley 1982 |
| *Tetranychus cinnabarinus* (Boisduval) | <8 | | 10.6 | 7.0 | 30 | Hazan *et al.* 1974 |
| | <7 | | 8.5 | 6.0 | 35 | |
| *Tetranychus mcdanieli* McGregor | 8.1 | | 10.5 | | 35 | Tanigoshi *et al.* 1975*a* |
| | | | | 5.5 | 34 | Roy *et al.* 2002 |
| | | | | 10.8 | 25.5 | Tanigoshi and Browne 1978 |
| *Eotetranychus orientalis* Klein | 8.2 | | | 5.9 | 29 | Rasmy 1978 |
| *Tetranychus evansi* Baker and Pritchard | 9.9 | | | 9.0 | 23.3 | Qureshi *et al.* 1969 |

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**Table 3** (*continued*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Eotetranychus hicoriae* (McGregor) | 10 | (13.1) | | 8.5 | 32.2 | Micinski *et al.* 1979 |
| | | | | 7.5 | 32.2 | Jackson *et al.* 1983 |
| *Oligonychus coffeae* (Nietner) | (10.2) | | (15.5) | 9.5 | 32 | Gotoh and Nagata 2001 |
| | 12.3 | | 17.6 | 11.5 | 30 | |
| | 10.3 | | | 9.4 | 30 | Das and Das 1966 |
| *Tetranychus ludeni* Zacker | 10.3 | | 15.5 | 9.2 | 27 | Mallik and ChannaBasavanna 1983 |
| *Tetranychus kanzawai* Kishida | 11.0 | | 16.5 | 9.3 | 25 | Gotoh and Gomi 2003 |
| *Schizotetranychus schizopus* (Zacher) | 11.5 | | 16.1 | 10.4 | 25 | Gotoh 1983 |
| *Tetranychus parakanzawai* Ehara | 11.6 | | 18.4 | 9.3 | 25 | Gotoh and Gomi 2003 |
| *Oligonychus ununguis* (Jacobi) | 11.95 | | 18.0 | 10.4 | 25 | Saitô 1979 |
| | 14.3 | | 17.4 | 12.1 | 29 | Boyne and Hain 1983*a* |
| | | | | 11.3 | 26 | Kramer and Hain 1989 |
| *Panonychus citri* (McGregor) | 12.0 | | | 11.0 | 26 | Beavers and Hampton 1971 |
| | 13.5 | | 19.7 | 12.0 | 25 | Saitô 1979 |
| *Eotetranychus uncatus* Garman | 12.7 | | 18.7 | 11.4 | 25 | Gotoh 1987*a* |
| *Oligonychus ilicis* (McGregor) | 13.1 | (15.5) | | 12.6 | 35 | Childs *et al.* 1984 |
| | 13.7 | | | 12.5 | 24 | Mague and Streu 1980 |
| *Schizotetranychus leguminosus* Ehara | 13.1 | | 19.1 | 11.75 | 25 | Gotoh 1983 |
| *Panonychus akitanus* Ehara | 13.2 | | 22.3 | 11.6 | 25 | Gotoh 1987*c* |
| *Eotetranychus carpini* (Oudemans) | 13.4 | | 20.1 | 12.0 | 25 | Castalogni *et al.* 1989 |
| *Eotetetranychus borealis* (Ewing) | | | 21.45 | 12 | 30 | Bounfour and Tanigoshi 2001 |
| *Eotetranychus sudanicus* Elbadry | 13.5 | | | 11.2 | Greenhouse | Siddig and Elbadry 1971 |
| *Tetranychus arabicus* Attiah | 13.6 | | | 12.4 | 27 | Attiah *et al.* 1978 |
| *Eotetranychus tiliarium* (Hermann) | 13.8 | | 21.0 | 12.4 | 25 | Gotoh 1987*a* |
| | 16.5 | | | 14.1 | 23–25 | Kropczynska *et al.* 1988 |
| *Oligonychus milleri* (McGregor) | 13.8 | | | 12.8 | 30 | Landwehr and Allen 1982 |
| *Tetranychus viennensis* Zacher | 13.9 | | 22.1 | 12.1 | 25 | Gotoh 1986 |
| *Aponychus corpuzi* Rimando | 14.1 | | 22.0 | 12.5 | 25 | Saitô and Ueno 1979 |
| *Eotetranychus pruni* (Oudemans) | 14.2 | | 19.9 | 13.7 | 24 | Grissa-Lebdi *et al.* 2002 |
| *Mononychellus progresivus* Doreste | | | 14.4 | 9.9 | 26 | Bonato *et al.* 1995 |

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**Table 3** (*concluded*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Schizotetranychus cercidiphylli* Ehara | 14.9 | | 20.4 | 13.8 | 25 | Gotoh 1983 |
| *Panonychus ulmi* (Koch) | 15.0 | | 22.7 | 13.7 | 25 | Gotoh 1987*b* |
| | | | | 5.6 | 25 | Osakabe *et al.* 1990 |
| | 17.8 | | 21.3 | 14.0 | 21 | Herbert 1981*a* |
| *Oligonychus gossypii* (Zacher) | | | 15.1 | 10.2 | 26 | Bonato *et al.* 1995 |

**Note:** Conventions as in Table 1.

period, usually with feeding, and a long adult life. A minimum generation time of 13 d at 27 °C is known in the small predaceous staphylinid *Atheta coriarae* (Kraatz) (Miller and Williams 1983). A few predaceous coccinellids may have life cycles of just under 15 d, because egg to adult development in some species is as fast as 10.4–13 d at about 30 °C (McMullen 1967; Obrycki and Tauber 1978, 1981, 1982; Miller 1992; Miller and Paustian 1992; Giles *et al.* 2001; Roy *et al.* 2002) and preoviposition intervals in the same or similar species, though commonly prolonged (Phoofolo and Obrycki 2000), are as short as 4.5 or even 3.5 d (*e.g.*, Brown 1972; Francis *et al.* 2001; Stathas *et al.* 2001). Some other beetles have minimum generation times of less than 20 d, as in some chrysomelids with rapid larval development and short preoviposition intervals and, exceptionally, curculionids (Buckingham and Bennett 1981). Although some additional species of beetles might be found with life cycles of less than 15 d under very favourable conditions, in most families and species minimum, and especially mean, generation times are long or very long.

### *Diptera*

Several species of Nematocera develop rapidly (Table 9). Mosquitoes, especially the species of temporary pools, are well known for rapid larval and pupal development. However, in many species of *Aedes* and other genera there is a long interval before the eggs hatch, and some species of *Aedes* characteristic of cool-temperate annual temporary ponds overwinter as eggs and are univoltine. Egg to adult development may take only 7–10 d in some species of *Culex* and *Anopheles*, but in most species reproduction after emergence is delayed by the need for mating, blood feeding, and egg development, which commonly take a week or more (*e.g.*, Cônsoli and Williams 1978; Okazawa *et al.* 1991). Therefore, although rapid life cycles do occur, they are not especially common.

Most larval chironomid midges are broadly saprophagous. They are abundant and may develop rapidly in eutrophic habitats. The prereproductive period is usually short, giving the fastest-developing species life cycles of 10–12 d in the laboratory (Table 9). Even shorter generation times may occur in the field; for example, species of Chironomini and Tanytarsini complete larval growth in only 5 to 6 d (Hauer and Benke 1991).

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**Table 4.** Sample records of short life cycles in other prostigmatic mites.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| **Pyemotidae** | | | | | | |
| *Pyemotes tritici* (Lagrèze-Fossat and Montané) | 4.0 | | | | 26 | Bruce 1984 |
| **Acarophenacidae** | | | | | | |
| *Acarophenax mahunkai* Steinkraus and Cross | | | | 4 | 23–26 | Steinkraus and Cross 1993 |
| *Adactylidium* sp. | | | | 4 | 30 | Elbadry and Tawfik 1966 |
| **Pygmephoridae** | | | | | | |
| *Pediculaster flechtmanni* (Wicht) | 5.2 | (7.2) | | 3.6 | 21/27 | Cross and Kaliszewski 1988 |
| **Tarsonemidae** | | | | | | |
| *Polyphagotarsonemus latus* (Banks) [*Tarsonemus*] | 4.5 | | | 3 | 27 | Hambleton 1938; Jeppson *et al.* 1975 |
| *Steneotarsonemus spinki* Smiley | 5.5? | | | 3? | 30 | Lo and Ho 1979 |
| *Tarsonemus granarius* Lindquist | 7.1 | | 10.4 | 5.0 | 30 | White and Sinha 1981 |
| *Tarsonemus myceliophagus* Hussey | 8 | | | 6 | 24 | Hussey and Gurney 1967 |
| *Iponemus confusum* (Lindquist and Bedard) [*Tarsonemoides*] | (10+) | | | 7.5 | 26.7 | Lindquist and Bedard 1961; Lindquist 1986 |
| **Cheyletidae** | | | | | | |
| *Cheyletes malaccensis* Oudemans | 12.7 | | | 11.3 | 30 | Yousef *et al.* 1982*a* |
| **Stigmaeidae** | | | | | | |
| *Agistemus excertus* Gonzalez | 7.5 | | | 6.4 | | Hafez *et al.* 1983 |
| | 9.7 | | | 7.3 | 28.5–30 | Zaher *et al.* 1971 |
| | 14.3 | | | 9.9 | 30.5 | Yousef *et al.* 1982*b* |
| *Zetzellia mali* (Ewing) | (14.5) | | <21 | 13.0 | 24 | White and Laing 1977 |
| **Diptilomiopidae** | | | | | | |
| *Rhyncaphytoptus ficifoliae* Kiefer | 7.15 | | 14.6 | 6.5 | 29 | Abou-Awad *et al.* 1999*b* |
| **Eriophyidae** | | | | | | |
| *Metaculus mangiferae* (Attiah) | 7.5 | | | 5 | 27 | Abou-Awad 1981 |
| *Phyllocoptruta oleivora* (Ashmead) | | | 8.85 | 6.1 | 29 | Allen *et al.* 1995 |
| *Epitrimerus pyri* (Nalepa) | (10.5) | | | 8 | 25 | Bergh 1994 |
| *Aceria ficus* (Cotte) | 12.45 | | 17.9 | 11.75 | 29 | Abou-Awad *et al.* 1999*b* |
| *Eriophyes datura* Soliman and Abou-Awad | 14.0 | | | 10.2 | 26 | Abou-Awad 1980 |
| *Vasates lycopersicae* (Massee) | | | | 6.5 | 30 | Rice and Strong 1962 |

**Note:** Conventions as in Table 1.

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**Table 5.** Sample records of short life cycles in astigmatic mites.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| **Acaridae** | | | | | | |
| *Sancassania boharti* (Cross) | 6.8 | | | 5.6 | 26 | Cross and Bohart 1990 |
| *Acotyledon formosani* Phillipsen and Coppel | 7.0 | | | | 30 | Phillipsen and Coppel 1977*a* |
| | | | 9.6 | | 25 | |
| *Caloglyphus anomalus* Nesbitt | 7.25 | | | 6.0 | 30 | Pillai and Winston 1969 |
| | (11) | (19) | | 9.5 | 23 | Woodring 1969 |
| | | | 18.4 | 9.7 | 27.8 | Barker 1974 |
| *Histiogaster* sp. | (7.3) | (?15) | | 7.1 | 30 | Okabe 1993 |
| | | | | 6.9 | 33 | |
| *Caloglyphus berlesi* (Michael) | 7.5 | | | 6.6 | 25 | Timms *et al.* 1981 |
| | 9 | | | | 26.7 | Pimentel *et al.* 1960 |
| | 11.5 | | 14 | 8.1 | 27 | Rodriguez and Stepien 1973 |
| *Tyrophagus putrescentiae* (Schrank) | | | 14.1 | 9.1 | 32.2 | Barker 1967 |
| | | | | 7.2 | 30 | Sánchez-Ramos and Castañera 2001 |
| | | | | 10.9 | 30 | Rivard 1961 |
| *Histiogaster anops* Griffiths | 11.1 | | | 9.6 | 27 | Davis and Hunter 1963 |
| *Histiogaster rotundus* Woodring | (13) | (22) | | 12 | 23 | Woodring 1969 |
| *Rhizoglyphus robini* (Claparede) | (13) | | 19.5 | 11.1 | 27 | Gerson *et al.* 1983 |
| *Schwiebea falticus* Woodring | (13) | (26) | | 11.4 | 23 | Woodring 1969 |
| *Tyrophagus similis* Volgin | 13.6 | | 22.5 | 11.9 | 25 | Kasuga and Amano 2000 |
| *Schwiebea rocketti* Woodring | (15) | (27) | | 13.2 | 23 | Woodring 1969 |
| *Histiogaster arborsignis* Woodring | (15) | (27) | | 14.1 | 23 | Woodring 1969 |
| **Histiostomatidae (Anoetidae)** | | | | | | |
| *Histiostoma polypori* (Oudemans) | 3.7 | | | 3.1 | 26 | Behura 1957 |
| *Histiostoma cataglyphi* Yousef | 5.9 | | | 5.3 | 25 | Yousef *et al.* 1979 |
| *Histiostoma formosana* Phillipsen and Coppel | 6.9 | | | | 25 | Phillipsen and Coppel 1977*b* |

**Note:** Conventions as in Table 1.

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**Table 6.** Sample records of short life cycles in Aphidae (virginoparae).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Aphis glycines* Matsumura | 3.9 | | | 3.3 | 27 | Hirano *et al.* 1996 |
| *Rhopalosiphum padi* (L.) | 4.9 | | | 4.6 | 25 | Dean 1974 |
| | 4.9 | | | 4.6 | 27.5 | Asin and Pons 2001 |
| | 5.2 | | | 5.0 | 26 | Villanueva and Strong 164 |
| | 5.3 | | 12.4 | 4.7 | 26 | Elliott and Kieckhefer 1989 |
| | 6.3 | | | | 20 | Simon *et al.* 1991 |
| *Aphis gossypii* Glover | 5.0 | (8) | | | 26 | Pettit *et al.* 1994 |
| | 5.2 | | 6.4 | 4.6 | 30 | Xia *et al.* 1999 |
| | 5.5 | | | 4.0 | 25 | Aldyhim and Khalil 1993 |
| | 6.0 | | | | Field | Saha and Raychaudhuri 1996 |
| | | | 7.3 | 4.1 | 25 | Perng 2002 |
| | 6.2 | | 7.4 | | 29.7 | Komazaki 1982 |
| | | | 10.4 | 4.5 | 30 | Kersting *et al.* 1999 |
| *Aphis fabae* Scopoli | 5.4 | (10.4) | | 5.4 | 28.5 | Tsitsipis and Mittler 1976 |
| | (6) | | | (6) | 25 | |
| | 6.7 | | 12.2 | | 20 | Frazer 1972 |
| | 6.8 | | | | 25/20 | Fernandez-Quintanilla *et al.* 2002 |
| *Schizaphis graminum* (Rondani) | 5.5 | | | | 21/25 | Kerns *et al.* 1989 |
| | 5.7 | | | | 27.7 | Peters *et al.* 1988 |
| | | | | 4.8 | 30 | Kirkland *et al.* 1981 |
| | | | | 5.1 | 25 | |
| | 8.2 | | 13.7 | | 21 | Sumner *et al.* 1986 |
| | | | 13.8 | 4.1 | 24 | Michels *et al.* 1997 |
| | 8.6 | | | | 27–29 | Girma *et al.* 1990 |
| *Aphis craccivora* Koch | | | 5.8 | | 20 | Gutierrez *et al.* 1971 |
| | | | | 5.1 | 25 | Abdel-Malek *et al.* 1982 |
| *Aphis spiraecola* Patch [*A. citricola* van der Groot] | 5.5 | | 7.4 | | 27.2 | Komazaki 1982 |
| | 7.3 | | 11.7 | | 25 | Neubauer *et al.* 1981 |
| | (8) | | 11.4 | 7.3 | 28 | Wang and Tsai 2000 |

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**Table 6** (*continued*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Lipaphis erysimi* (Kaltenbach) | | | | 5.0 | 30 | Liu and Meng 2000 |
| | 5.8 | | | | 28.4 | Rout and Senapati 1968 |
| *Toxoptera aurantii* (Boyer de Fonscolombe) | (6.0) | | 9.5 | 5.3 | 28 | Wang and Tsai 2001 |
| *Rhopalosiphum maidis* (Fitch) | 6.2 | (10) | | 5.5 | 28/24 | Branson and Ortman 1967 |
| *Acyrthosiphon pisum* (Harris) | | | | 4.9 | 25 | Lamb 1992 |
| | | | | 5.4 | 26.1 | Campbell and Mackauer 1975*a* |
| | 6.6 | | 10.3 | | 26.1 | Campbell and Mackauer 1977 |
| | 6.6 | | | 5.7 | 21 | Kouamé and Mackauer 1992 |
| | | | 9.0 | 8.5 | 26.7 | Morgan *et al.* 2001 |
| | (7) | (10.3) | | 6.8 | 25 | Siddiqui *et al.* 1973 |
| | (7.2) | | (11.7) | 6.2 | 25 | Hutchison and Hogg 1984 |
| | 7.6 | | 11.3 | | 20 | Frazer 1972 |
| | 7.7 | | 12.6 | | 20 | Mackauer 1973 |
| | 8.0 | | | | 24 | Hughes and Bryce 1984 |
| | 9.0 | | | 7.2 | 20.1 | Cartier 1960 |
| | (9) | | 11.9 | 8.5 | 26.7 | Morgan *et al.* 2001 |
| | | | 13.7 | | | Campbell and Mackauer 1975*b* |
| *Toxoptera citricida* (Kirkaldy) | 6.2 | | 8.5 | | 27.6 | Komazaki 1982 |
| | | | 8.5 | 5.5 | 30 | Tsai and Wang 1999 |
| | 7.1 | | 9.4 | 6.3 | 30 | Tang *et al.* 1999 |
| *Brachycaudus rumexicolens* (Patch) | | | 7.2 | | 27.9 | Scott and Yeoh 1999 |
| *Aphis pomi* De Geer | | | | 5.2 | 28 | Carroll and Hoyt 1986*a* |
| | | | (11.6) | 5.1 | 25.8 | Graf *et al.* 1985 |
| | | | | 4.7 | 28 | Carroll and Hoyt 1986*b* |
| *Monelliopsis pecanis* Bissell | 6.3 | | 10.0 | 5.1 | Field | Kaakeh and Dutcher 1992 |
| *Rhopalosiphum insertum* (Walker) | | | (11.0) | 5.1 | 25.8 | Graf *et al.* 1985 |
| *Myzus persicae* (Sulzer) | 6.5 | | | 5.8 | 25 | El Din 1976 |
| | 6.8 | | | | 25/20 | Fernandez-Quintanilla *et al.* 2002 |
| | 7.0 | (10) | | | 26 | Pettit *et al.* 1994 |
| | | | 5.4 | | 26.7 | Jansson and Smilowitz 1985 |

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**Table 6** (*continued*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| | 7.6 | | | | 22 | Hodjat and Bishop 1978 |
| | | | | 5.25 | 22–29 | Eggers-Schumacher 1983 |
| | | | | 5.4 | 28 | Liu and Meng 1999 |
| | 7.8 | | | | 20 | Nikolakakis *et al.* 2003 |
| | | | 12.5 | 7.6 | 20 | Tamaki *et al.* 1982 |
| *Dysaphis plantaginea* (Passerini) | | | (10.9) | 6.15 | 25.8 | Graf *et al.* 1985 |
| *Aphis nasturtii* Kaltenbach | (<6.7) | | 9.2 | 5.7 | 30 | Wang *et al.* 1997 |
| | (<7.6) | | 8.3 | 6.6 | 35 | |
| *Acyrthosiphon kondoi* Shinji | 7.0 | | 10.1 | 5.8 | 26.7 | Summers *et al.* 1984 |
| | | | | 7.9 | 20 | Wellings 1985 |
| *Brachycaudus schwartzi* (Börner) | | | 10.4 | 7.6 | 30 | Satar and Yokomi 2003 |
| *Hyperomyzus lactucae* (L.) | (7) | | 11.1 | 6.7 | 24 | Liu and Hughes 1987 |
| | | | | 6.6 | 22 | Liu and Hughes 1984*b* |
| *Sitobion avenae* (Fabr.) [*Macrosiphum*] | 7.2 | | | 6.6 | 25 | Lykouressis 1985 |
| | 7.6 | | | | 20 | Simon *et al.* 1991 |
| | 8.2 | | | 7.3 | 25 | Asin and Pons 2001 |
| | 8.4 | | | 7.5 | 22.5 | Dean 1974 |
| | | | | 10.1 | 29 | Kieckhefer *et al.* 1989 |
| *Brachycorynella asparagi* (Mordvilko) | 7.4 | | 11.6 | | 21.7 | Wright and Cone 1988 |
| | 7.7 | (12) | | 7.7 | 23 | Hayakawa *et al.* 1990 |
| | | | 14.8 | 8.1 | 25 | Tamaki *et al.* 1983 |
| *Monellia caryella* (Fitch) | 7.5 | | 8.6 | 6.3 | Field | Kaakeh and Dutcher 1992 |
| *Metapolophium dirhodum* (Walker) | 7.8 | | | 7.4 | 20 | Dean 1974 |
| | 8.5 | | | 7.5 | 25 | Asin and Pons 2001 |
| | 13.0 | | | 11.9 | 15 | Grüber and Dixon 1988 |
| | | | | 12.4 | Field | Cannon 1984 |
| *Diuraphis noxia* (Kurdjumov) | 8.2 | (25.2) | | 8.2 | 20 | Aalbersberg and Du Torr 1987 |
| | | | | 8.6 | 27–29 | Girma *et al.* 1990 |
| | | | 8.6? | 9.9 | 30 | Nowierski *et al.* 1995 |
| *Rhopalosiphum nympheae* (L.) | | (8) | | 6.8 | 30.6 | Ballou *et al.* 1986 |

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**Table 6** (*concluded*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Tinocallis caryaefoliae* (Davis) [*Melanocallis*] | 9.1 | | 12.6 | 7.7 | Field | Kaakeh and Dutcher 1992 |
| *Aphis nerii* Boyer de Fonscolombe | | | 11.8 | | 30 | Kuo and Chiang 1999 |
| *Macrosiphum albifrons* Essig | 9.4 | | 16.6 | 7.4 | 24.2 | Frazer and Gill 1981 |
| *Pemphigus betae* Doane | 9.7 | | 14.2 | | 24 | Campbell and Hutchison 1995 |
| *Chaitophorus leucomelas* Koch | 10.5 | (17) | | 9.0 | 25 | Hintze-Podufal and Thorns 1979 |
| *Cinara watsoni* Tissot | 12.2 | | | 9.2 | 27.2 | Brooks and Warren 1964 |
| *Cinara* sp. (nr. *cupressi* (Buckton)) | | | 16.3 | 9.2 | 25 | Kairo and Murphy 1999 |
| *Eulachnus agilis* (Kaltenbach) | 13.3 | | | 12.0 | 21.1 | Bliss and Kearby 1971 |

**Note:** Conventions as in Table 1.

A few species of other small Nematocera develop very rapidly, too (Table 9). Some ceratopogonids develop rapidly, but adult blood feeding and egg development extend generation times and other reports, even for species shown in Table 9, record slower development. Larval feeding of many cecidomyiid midges is rapid (*e.g.*, Harris and Schreiner 1992), and the preoviposition period may last only one day (*e.g.*, Caresche and Wapshere 1975), but other stages are slower and only a few species can complete a generation in less than 15 d. However, when food is abundant, some fungivorous species have paedogenetic life cycles (much shorter than their sexual cycles) that have arisen in four distinct groups within the family (Wyatt 1967). At least one species of psychodid that eats decaying materials has a short generation time even though longer developmental times are more common, especially in the blood-feeding phlebotomines.

Among the Brachycera (Table 10), many cyclorrhaphan flies have relatively short life cycles, but few have very short ones. Scattered records suggest that egg to adult development can be completed in as little as 14 or 15 d in some Aschiza (*e.g.*, Patro and Behera 2002 for a syrphid). Among the acalyptrates, one might expect that families of small phytophagous flies that have been studied especially because of their agricultural relevance would contain rapidly developing species. However, almost all generation times are at least 15 d, typically because development throughout the life cycle is not especially rapid, because the pupal stage is relatively long (as in Agromyzidae), or because the preoviposition period is long (as in many Tephritidae). However, egg to adult development can take less than 15 d in a few species of Agromyzidae, including *Liriomyza trifolii* (Burgess) (*e.g.*, Leibee 1984; Miller and Isger 1985; Smith and Hardman 1986). *Drosophila melanogaster* Meigen develops rapidly in the laboratory, and even faster strains can be selected (Table 10). Some other acalyptrate families, such as Ephydridae (Table 10) and Piophilidae (Hegazi *et al.* 1978), also have species with very short life cycles, at least among those with short preoviposition periods.

The maggots of calyptrate flies such as the muscids, sarcophagids, and calliphorids that develop in decaying material, dung, or carrion are well known for their very rapid development. For example, Levot *et al.* (1979) reported larval developmental times of 2.25 to 5.2 d for eight species of calliphorids and one sarcophagid. A

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**Table 7.** Sample records of short life cycles in Anthocoridae.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Orius strigicollis* (Poppius) | | | | 11.4 | 30 | Ohta 2001 |
| *Orius sauteri* (Poppius) | (14.7) | | 21.9 | 12.7 | 30 | Nagai and Yano 1999 |
| | 16.0 | (26) | | 12.0 | 25 | Honda *et al.* 1998 |
| | | | | 11.9 | 30 | Nakata 1995 |
| *Orius minutus* (L.) | 14.7 | (25) | | 11.7 | 25 | Honda *et al.* 1998 |
| *Orius insidiosus* (Say) | | | | 8.3 | 35 | McCaffrey and Horsburgh 1986 |
| | | | | 12.1 | 32 | Isenhour and Yeargan 1981 |
| *Orius albidipennis* Reuter | | | 14.8 | 7.7 | 35 | Cocuzza *et al.* 1997 |
| | | | | 10.9 | 30 | Gitonga *et al.* 2002 |
| *Orius tristicolor* White | (14) | | | (11.5) | 33.3 | Askari and Stern 1972 |
| *Orius laevigatus* (Fieber) | | | 20.4 | 10.1 | 35 | Cocuzza *et al.* 1997 |

**Note:** Conventions as in Table 1.

**Table 8.** Sample records of short life cycles in Thripidae.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Thrips hawaiiensis* (Morgan) | 8.0 | | | 7.0 | 30 | Murai 2001*a* |
| *Scolothrips sexmaculatus* (Pergande) | 11.3 | | 17.9 | 10.6 | 30 | Coville and Allen 1977 |
| *Frankliniella fusca* (Hinds) | (12) | | 13.2 | 11.5 | 35 | Lowry *et al.* 1992 |
| *Thrips setosus* Moulton | 12.2 | | 19.6 | 11.2 | 25 | Murai 2001*b* |
| | | | | 10.4 | 30 | |
| *Thrips tabaci* Lindeman | 12.6 | | 16.9 | 10.6 | 30 | Murai 2000 |
| | 14.2 | | | 13.2 | 25 | Abdel-Gawaad and El-Shazli 1971 |
| | 14.8 | | 20.4 | 12.9 | 25 | van Rijn *et al.* 1995 |
| *Frankliniella occidentalis* (Pergande) | | (12) | | 9 | 26.5 | Lopes and Alves 2000 |
| | (14) | (16) | | 11.5 | 30 | Gaum *et al.* 1994 |
| | | | 24 | 12.0 | 25 | Hulshof *et al.* 2003 |
| | | | 29 | 11.7 | 25 | |
| | 14.2 | | 20.1 | 12.4 | 25 | van Rijn *et al.* 1995 |
| | (14.3) | | 15.5 | 13.8 | 25 | Lowry *et al.* 1992 |
| | 15.0 | | | 12.6 | 30 | Lublinkhof and Foster 1977 |
| *Thrips obscuratus* (Crawford) | 14.3 | | | 10.3 | 27 | Teulon and Penman 1991 |
| *Scirtothrips dorsalis* Hood | (14.4) | | | 13.4 | 20 | Tatara 1994 |
| | 14.4 | | | 13.4 | 29.4 | Tatara 1994 |
| | | | | 13.9 | 30 | Shibao 1996 |
| *Thrips palmi* Karny | | | 15.2 | 11.8 | 32 | Tsai *et al.* 1995 |

**Note:** Conventions as in Table 1.

few species have minimum generation times just below 15 d (Table 10). Nevertheless, stages other than larvae commonly take longer, and total generation times are not strikingly short in most species. In particular, in typical muscoid flies the teneral adult must harden, mate, feed, and develop eggs before oviposition, thus requiring preoviposition intervals of at least several days (*e.g.*, Parr 1962; Hughes *et al.* 1972; Kuramochi 1985). Larvae of some species of tachinid parasitoids not constrained by host development likewise develop very rapidly

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in their hosts, but again the life cycle is seldom very short because of longer pupal and preoviposition intervals. Mean generation times tend to be longer still because the oviposition period is prolonged.

### *Lepidoptera*

The typical phytophagous caterpillars of most Lepidoptera develop relatively slowly, as do the pupae. No species of Lepidoptera has strikingly rapid development. However, some small moths can complete egg to adult development in as little as 11 d (*e.g.*, Plutellidae: Liu *et al.* 2002) and a generation in 15 to 20 d (*e.g.*, Lyonetidae: Parrella and Kok 1977; Gelechiidae: Shanower *et al.* 1993), suggesting that a few species might have even shorter life cycles under especially favourable conditions.

### *Hymenoptera*

The order Hymenoptera contains both rapidly and slowly developing taxa. Most sawflies (phytophagous), bees (phytophagous), and wasps (predaceous) have relatively long and often seasonal life cycles. Species in many families of the suborder Apocrita, comprising chiefly parasitoids of other arthropods, develop rapidly. However, many other related species develop more slowly, especially on hosts with slow development. Species in which adults have complex behaviours for mating and feeding on the host less commonly have very short generation times.

Species in the major family Braconidae (including Aphidiinae, solitary parasitoids of aphids) attack many kinds of insects. Many species of internally and externally feeding species attacking hosts in various taxa, especially the host larval stages, have rapid larval development and short preoviposition intervals, giving minimum life cycles of 10 to 15 d (Table 11). There are numerous other reports of related species with rapid larval development that undoubtedly also have similarly short cycles. Many more species with somewhat longer cycles are known. The major family Ichneumonidae likewise contains diverse, mostly solitary parasitoids of arthropods, but very few species complete a generation in less than 15 d (Table 11). However, many species have only slightly longer generation times (*e.g.*, Giron 1978; Isenhour 1986; Smith *et al.* 1990). Some species with rapidly developing larvae spend much more time in the pupal stage (*e.g.*, Rahoo and Luff 1987). In typical species, reproduction is prolonged, extending mean generation times.

Rapid development is characteristic of several families of small chalcidoids (Table 12), typically endoparasitoids or hyperparasitoids of insects. Mymarids and trichogrammatids parasitize chiefly eggs; eulophids and elasmids attack eggs, larvae, or pupae; aphelinids specialize chiefly on aphids and scale insects; and pteromalids have a wide range of mainly larval and pupal hosts. A few encyrtids have life cycles close to 15 d (*e.g.*, Umeh 1988), but most species have longer life cycles. Other hymenopterous parasitoids with rapid development in the larval stage (Table 13) include scelionids, which attack insect eggs and typically have very short preoviposition intervals, ceraphronids (*e.g.*, 9.4 d for immature development of *Dendrocerus niger* (Howard) at 25.9 °C: Campbell and Mackauer 1975*a*), and a few species of bethylids, although most species take much longer to develop, attacking chiefly larvae.

## Correlates of short life cycles

### Phylogeny

The above taxonomic review shows that short life cycles are much more prevalent in some taxa than in others. Taxa containing species with life cycles of less than 15 d are summarized in Table 14. The distribution of taxa suggests that phylogenetic origin and evolutionary advancement, as well as ecological niche and body size, govern the rate of development.

In general, highly derived groups develop more rapidly than their primitive relatives. Primitive groups tend to retain many moults: up to 30 in Thysanoptera (Nishizuka *et al.* 1998), normally 15–25 in mayflies (Fink 1980; Brittain 1982), and up to 24 in stoneflies (Vaught and Stewart 1974; Baumann 1987). Most families of flies, wasps, and other endopterygotes develop more rapidly than exopterygotes such as orthopterans. Even in oribatid mites (most of which develop slowly), the phylogenetically advanced species develop more rapidly than more primitive ones (Lebrun 1970, 1971). However, life cycles that have become complex tend to be prolonged (*e.g.*, Proctor and Pritchard 1990 for water mites).

Few species with very long adult lives have short generation times. Therefore, many well-known families of beetles and other insects are missing from the list in Table 14.

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**Table 9.** Sample records of short life cycles in Nematocera.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| **Culicidae** | | | | | | |
| *Culex tritaeniorhynchus* Giles | 10.6 | | 22.2 | (~8) | 27–29 | Reisen *et al.* 1979 |
| | (18.5?) | | (~21) | 8.5 | 28 | Shahid and Reisen 1981 |
| *Culex nigripalpis* Theobald | | | | 7.5 | 32? | Nayar 1968 |
| *Anopheles albimanus* (Wiedemann) | (13.1) | | 18 | (10.3) | 26 | Mahmood 1997 |
| *Culex pipiens* L. | (14.7) | | | 8.2 | 30 | Madder *et al.* 1983 |
| *Anopheles sinensis* Wiedemann | | | | 14.4 | 28 | Shono and Hirano 1993 |
| **Chironomidae** | | | | | | |
| Chironomini and Tanytarsini spp. | | | | 5–6 | Field, 21–24 | Hauer and Benke 1991 |
| Various species | | | | 9–16 | 22 | Gray 1981 |
| *Chironomus strenzkei* Fittkau | 10 | (12) | | | 28 | Syrjämäki 1965 |
| *Chironomus sancticaroli* Strixino and Strixino | 12 | | | 11 | 25 | Strixino and Strixino 1982 |
| *Chironomus* sp. nr. *attenuatus* Walker | (12?) | | | (10) | 28.9 | Biever 1965 |
| *Chironomus circumdatus* (Kieffer) | | | | 12 | 37 | Sankarperumal and Pandian 1991 |
| *Tanytarsus dissimilis* Johansen | 12.2 | | | 12 | 28 | Nebeker 1973 |
| *Chironomus imicola* Kieffer | (14) | | | 12.2 | Field | McLachlan 1983 |
| *Corynoneura scutellata* Winnertz | | | | 10.5 | 25 | Olsen *et al.* 2003 |
| *Chironomus pulcher* Wiedemann | | | | 13.3 | 30 | Dejoux 1971 |
| **Ceratopogonidae** | | | | | | |
| *Culicoides variipennis* (Coquillett) | 14? | | | | Field | Barnard and Jones 1980 |
| | | | | 10? | 23–25 | Boorman 1974 |
| | | | | 14.5 | 30 | Mullens and Rutz 1983 |
| *Culicoides brevitarsis* Kieffer | | | | 11–13 | 26–33 | Allingham 1991 |
| | | 17 | | | 28 | Bishop *et al.* 1996 |
| *Probezzia* sp. | | | | 11.5 | 22 | Gray 1981 |
| **Cecidomyiidae** | | | | | | |
| *Feltiella acarisuga* (Vallot) | (12?) | | | 10 | 27 | Gillespie *et al.* 2000 |
| *Feltiella minuta* (Felt) | | (12) | | 9.5 | 30 | Ho and Chen 1998 |
| *Contarinia sorghicola* (Coquillet) | (12.5) | | | 11.9 | 36 | Baxendale *et al.* 1984 |

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**Table 9** (*concluded*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Mycophila speyeri* (Barnes) (paedogenetic generation) | 6 | | | 5 | ? | Wyatt 1964 |
| | | | | 4 | 25 | Ulrich *et al.* 1972 |
| *Heteropeza pygmaea* Winnertz (paedogenetic generation) | 7 | | | 6 | ? | Wyatt 1963 |
| *Miastor metraloas* Meinert (paedogenetic generation) | 12 | | | 5 | ? | Wyatt 1967 |
| **Psychodidae** | | | | | | |
| *Psychoda alternata* Say | (15?) | | | 13.1 | 24 | Redborg *et al.* 1983 |

**Note:** Conventions as in Table 1.

Finally, even in families characterized by rapid development there may be genera with slower or much slower development. For example, species of *Mansonia* have slower larval development than many other mosquitoes.

## Strain

Different strains within a species may differ widely in life-cycle duration. Typically there are differences among populations from different regions (or among different laboratory colonies). Many of the intraspecific differences shown in Tables 1–13, albeit modified by food and other experimental conditions, reflect such differences among geographic strains. The strain differences accord chiefly with differential selection in places with different conditions (see review by Danks (1987), Chapter 9), but some of them result from other factors. For example, sublethal pathogens typically slow down the development of their hosts but can have the reverse effect: the aphid *Sitobion avenae* (Fabr.) takes 7.9 d to develop when infected by virus but 9.3 d when not infected (Fereres *et al.* 1989).

Different aphid clones collected in the same place may differ. For example, minimum generation time of *Rhopalosiphon padi* (L.) lasts from 6.3 to 8.1 d, depending on strain (Simon *et al.* 1991), and immature development of *S. avenae* lasts from 6.6 to 9.4 d (Lykouressis 1985). Such differences may also accord with other traits of interest, such as resistance to insecticides (*e.g.*, Eggers-Schumacher 1983).

## Rapid development in all stages

For complete life cycles to be very short, all stages must develop relatively rapidly. In contrast, for various reasons, most groups of insects spend much longer in one or more particular stages than in the others, even during diapause-free development. Short *mean* generation times occur chiefly in species in which the majority of offspring are produced soon after reproduction begins. Most such species have relatively short adult lives (*e.g.*, Trichogrammatidae), and many of them do not feed as adults.

Such patterns in the life cycle, some of which were noted in the taxonomic review, depend largely on phylogeny. For example, even some small insects with relatively rapid larval and pupal development (*e.g.*, tingids, thrips) require longer periods for egg development. In other taxa, the larval stages are somewhat prolonged (*e.g.*, cicadellids, most families of moths). A relatively long pupal stage is characteristic of

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**Table 10.** Sample records of short life cycles in Brachycera.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| **Cyclorrhapha: Acalyptratae** | | | | | | |
| **Agromyzidae** | | | | | | |
| *Liriomyza sativae* Blanshard | (14) | (<18) | | 13.1 | 30 | Parkman *et al.* 1989 |
| **Ephydridae** | | | | | | |
| *Scatella stagnalis* Fallen | 14.6 | | 18.4 | 11.4 | 25 | Vänninen 2001 |
| | | | | 10.1 | 28.5 | |
| *Scatella picea* (Walker) | 15 | | | 12.8 | 24 | Connell and Scheiring 1982 |
| **Drosophilidae** | | | | | | |
| *Drosophila melanogaster* Meigen | | | | | | |
| Selected line | (9) | | | 7.9 | 25 | Chippindale *et al.* 1997 |
| Selected line | | | | 6.2 | 25 | Prasad *et al.* 2000 |
| | (10.5) | | | 9.0 | 25 | Summary of others by Chippindale *et al.* 1997 |
| | | | | 9 | 25 | Bakker and Nelissen 1963 |
| **Cyclorrhapha: Calyptratae** | | | | | | |
| **Muscidae** | | | | | | |
| *Stomoxys calcitrans* (L.) | (14) | | (24) | 12 | 30 | Lysyk 1998*a* |
| | | | | 13.7 | 35 | Kunz *et al.* 1977 |
| *Musca domestica* L. | 15.1 | | | 10.5 | 28 | Mishra 1979 |
| | | | | 8.8 | 35 | Lysyk and Axtell 1987 |
| *Musca vetustissima* Walker | | | | 7.1 | 38 | Vogt *et al.* 1990 |
| *Fannia femoralis* (Stein) | | | | 14.4 | 30 | Meyer and Mullens 1988 |
| *Haematobia thirouxi potans* (Bezzi) | | | | 9.4 | 30 | Fay 1985 |
| *Haematobia irritans* (L.) | | | | 9.3 | 30 | Depner 1961 |
| | 20 | | | 15.3 | 25 | Lysyk 1991 |
| **Calliphoridae** | | | | | | |
| *Chrysomyia rufifacies* (Macquart) | ~15? | | | ~9 | ~30 | Baumgartner 1993 |
| | | | | 7.9 | 35 | Byrd and Butler 1997 |
| *Protophormia terraenovae* (Robineau-desvoidy) | | | | 9.2 | 35 | Greenberg and Tantawi 1993 |
| *Phaenicia pallescens* (Shannon) | | | | 10.4 | 35 | Ash and Greenberg 1975 |
| *Phormia regina* (Meigen) | | | | 11 | 35 | Byrd and Allen 2001 |

**Note:** Conventions as in Table 1.

several families of flies (*e.g.*, agromyzids, muscids). Finally, many species with rapid larval and pupal development mature eggs only after a relatively long preoviposition interval, often requiring adult foods, as in many Coleoptera and Diptera. A characteristic of nearly all of the species listed in Tables 1–13 is that these sorts of stage-specific delays are minimized, except in some mites in which larval development is so rapid that it can compensate for a relatively long-lasting egg stage (*e.g.*, Bounfour and Tanigoshi 2001). Short life cycles are virtually unknown in species with complex social interactions, including ants and their inquilines, or in species with resistant dormant stages, except when these stages can be omitted in

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favourable conditions (as for the hypopal stages of some mites). Moreover, dormancy responses include not only complete suppression of development but also the slowing of development in response to token stimuli such as photoperiod, and there are also several more complex options. This remarkable range of responses for adaptive timing of the life cycle in insects as a whole (Danks 2002*a*), coupled with the normal stage-specific delays just summarized, means that relatively few species develop rapidly in all stages.

**Size**

Species of small size are more likely to develop rapidly than larger ones. Not only do fewer resources have to be accumulated, but also metabolic rate is faster in smaller organisms (Schmidt-Nielsen 1984). Many of the characteristic families shown in Table 14 contain mainly small species. These taxa with short life cycles consist chiefly of mites, small flies, and parasitoid wasps attacking hosts of small size, especially eggs, or living gregariously on their hosts (*e.g.*, many chalcidoids). Within a given family, the smaller species typically develop most rapidly (see below). Nevertheless, even among small parasitoids such as mymarids there are species with relatively slow development. Moreover, Walter and Proctor (1999, Fig. 4.7) showed that developmental rates were similar in 15 species of mesostigmatid mites differing in size by more than an order of magnitude.

**Temperature**

Rapid development takes place at high temperatures, and short life cycles are best known from laboratory rearing at the temperature at which development is fastest. Norton (1994) pointed out that much laboratory rearing has been carried out at temperatures much higher than those normally experienced in the field. Some field observations suggest that development may be slower in the field than in warm, well-fed laboratory colonies (Mackey 1977). Nevertheless, many natural habitats are relatively warm and, moreover, warm microhabitats can be chosen by individuals during development or by ovipositing females and enhanced by basking behaviour (see Habitat). Indeed, many short life cycles have been reported from the field as well as the laboratory.

Typically, as temperature increases, developmental rate increases up to a maximum and then declines again as the temperature reaches an unsuitable level. For an outline of such features and models and many further references see Laudien (1973), Lamb *et al.* (1984), Lactin *et al.* (1995), and Danks (2000). However, the temperatures at which larval/nymphal growth, larval/nymphal survival, postemergence egg development, fecundity, or adult survival are maximized may be different, potentially resulting in different temperatures for the fastest immature development, shortest minimum or mean generation times, and maximum reproductive rate. The effects of temperature on generation time are exemplified by data for the eriophyiid mite *Phyllocoptruta oleivora* (Ashmead) (Allen *et al.* 1995). Mean calculated generation time is 8.85 d at 29 °C, is slower at higher temperatures (9–10 d at 31–33 °C), and is much slower at low temperatures (37.2 d at 14 °C).

Not only the level but also the consistency of temperature is important. Cold nights may greatly slow development even when days are hot. Therefore, short life cycles in nature have been reported especially from tropical and subtropical regions, which maintain fairly constant temperatures throughout the diel, and from warm stable habitats (see Habitat).

**Food**

Some species that eat very nourishing food in continuous supply develop very rapidly in the larval stage (Plowright and Pendrel 1977 for *Bombus* larvae). Food of poor quality or in limited supply greatly slows development even in species capable of fast growth. For example, in the phytoseiid mite *Phytoseius plumifer* (Canestrini and Fanzago), mean female immature development varied from 3.8 d on a diet of immature spider mites to 10.5 d on date pollen (Zaher *et al.* 1969). A similar pattern is seen in many other species of mites and insects. Many studies of herbivores, such as aphids, show how different host plants affect developmental rates. In one typical example, immature development of *Aphis gossypii* Glover varied from 4.1 to 8.2 d on different hosts, and calculated generation time varied from 7.3 to 12.7 d (Perng 2002). A number of the papers listed in Table 6 report similar results. Thus, in nature the potential growth rate of some herbivores changes through the season in parallel with changes in foodplant quality (*e.g.*, levels of fibre, nutrients, water, or antifeedants) that influence the duration of feeding and growth (*e.g.*, Yang and Joern 1994). In some species the effect of food plants

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**Table 11.** Sample records of short life cycles in Braconidae and Ichneumonidae.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| **Braconidae** | | | | | | |
| *Bracon instabilis* Marsh. | (9.5) | | | 9.2 | 30 | Abbas and Abou-Zeid 1983 |
| *Lysiphlebus testaceipes* (Cresson) | (10) | | | (9.5) | 24 | Tyler and Jones 1974 |
| | | | | 8.9 | 26 | Royer *et al.* 2001 |
| | | | | 12.4 | 24 | Salto *et al.* 1983 |
| *Trioxys utilis* Muesebeck | 10 | | | 10 | 21.1 | Schlinger and Hall 1961 |
| | | | 11.6 | 9.3 | 29.4 | Force and Messenger 1964 |
| *Bracon kirkpatricki* (Wilkinson) | 10.1 | | | 7.6 | 35 | Engroff and Watson 1975 |
| *Aphidius gifuensis* Ashmead | (10.5) | | | 9.7 | 25 | Ohta *et al.* 2001 |
| | | | 13.2 | | | Ohta and Ohtaishi 2004 |
| *Microplitis brassicae* Muesebeck | 10.7 | (15) | | 10.7 | 32.2 | Browning and Oatman 1985 |
| *Aphidius colemani* Viereck | (11.0) | | | 10.0 | 25 | van Steenis 1993, 1995 |
| *Microplitis rufiventris* Kokujev | (11.4) | | | 10.9 | 30 | Hutchison *et al.* 1986 |
| | (14.1) | | | 13.6 | 26 | McCutcheon and Harrison 1987 |
| | | | | 13.1 | 28 | Altahtawy *et al.* 1976 |
| *Praon palitans* Muesebeck | 11.9 | | | 10.5 | 21.1 | Schlinger and Hall 1960 |
| *Leiophron uniformis* (Gahan) | (12) | | | 9.8 | 25 | Debolt 1981 |
| *Apanteles marginiventris* (Cresson) | (12) | | | (12) | 30 | Boling and Pitre 1970 |
| | | | | 12.2 | 30 | Kunnalaca and Mueller 1979 |
| *Cotesia plutellae* (Kurdjumov) | (<12.4) | | | 11.4 | 25 | Kawaguchi and Tanaka 1999 |
| *Bracon* sp. (?*hancocki* (Wilkinson)) | 12.5 | | | 10.0 | 24–30 | Olaifa and Akingbohungbe 1982 |
| *Aphidius rhopalosiphi* De Stefani-Perez | (12.8) | | | 11.3 | 25 | Sigsgaard 2000 |
| *Ephedrus californicus* Baker | (12.8) | (17.3) | | 12.3 | 26.4 | Cohen and Mackauer 1987 |
| *Microplitis feltiae* Muesebeck | | | | 12.3 | 30 | Puttler and Thewke 1970 |
| *Aphidius sonchi* Marshall | 12.8 | | | 12.5 | 20 | Liu and Carver 1985 |
| | | | | 9.1 | 26 | Liu and Hughes 1984*a* |
| | | | | 11.0 | 22 | |
| | | | 13.1 | | 22 | Liu 1985 |
| *Aphidius ervi* Haliday | (13.1) | | | 11.6 | 25 | Sigsgaard 2000 |
| | | | | 10.1 | 25.9 | Campbell and Mackauer 1975*b* |
| *Aphidius smithi* Sharma and Subba Rao | | | | 9.5 | 21 | Fox *et al.* 1967 |
| | | | | 9.9 | 25.9 | Campbell and Mackauer 1975*b* |
| | | | 15.7 | (12.5) | 20.5 | Mackauer 1983 |

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**Table 11** (*concluded*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Diaeretiella rapae* (M'Intosh) | (14) | (15) | | 13.7 | 30 | Hayakawa *et al.* 1990 |
| *Bracon hebetor* Say | (14) | | 20 | 13 | 27 | Nikam and Pawar 1993 |
| | | | | 6.7 | 35 | Jackson and Butler 1984 |
| *Meteorus autographae* Muesebeck | (14.5) | (20) | | 14.0 | 27 | Grant and Shepard 1984 |
| *Orgilus elasmopalpi* Muesebeck | (15?) | | | 14.1 | 32.2 | Johnson and Smith 1980 |
| **Ichneumonidae** | | | | | | |
| *Diadromus collaris* (Gravenhorst) | (11) | | | 10.4 | 30 | Liu *et al.* 2001 |
| *Hyposoter exiguae* (Viereck) | (15) | | | 14 | 32.2 | Browning and Oatman 1981 |
| | | | | 12.8 | ? | Bloem and Duffy 1990 |
| | | | | 14 | 26 | Jowyk and Smilowitz 1978 |

**Note:** Conventions as in Table 1.

on developmental rate depends on the instar, and the differences among food plants may even be reversed from one instar to another (Capinera *et al.* 1981).

Similar food-related differences take place in species in other circumstances, including aquatic species (*e.g.*, Meier and Torres 1978; Richardson 1991) and parasitoids. In many parasitoids, developmental rate depends not only on the host species but also on host condition, size, or instar (*e.g.*, Fox *et al.* 1967; Weseloh 1984; Umeh 1988; Liu and Stansly 1996), and even on the food eaten by the host (*e.g.*, Altahtawy *et al.* 1976). Predators as well as parasitoids are very well represented among the fast-developing taxa.

Species that use rich but ephemeral sources of food must develop rapidly to exploit the source before it becomes unsuitable, disappears, or is preempted by competitors. For example, larval development of flies living in dung and carrion is characteristically rapid (Greenberg and Tantawi 1993). Many species in decaying vegetation and fungi, including paedogenetic cecidomyiids, also characteristically develop rapidly.

## Other factors

Some other conditions are occasionally but not consistently correlated with generation time through their effect on larval growth rate. Photoperiod modifies growth rate directly in a surprisingly large number of insect species (Abdel-Malek *et al.* 1982 and Aldyhim and Khalil 1993 for *Aphis* spp.; Table 33 in Danks 1987). In some species, especially species of small mites, growth rate depends on humidity (*e.g.*, Bonato *et al.* 1995). Growth rates can also depend on density: development may be more rapid under crowded conditions (see review by Danks (1987)). There are some unexpected effects too: two species of whiteflies develop more rapidly in mixed cultures than when reared separately (Tsueda and Tsuchida 1998).

## Habitat

The habitat type of a given species is especially important because temperature and food availability greatly affect developmental rate. Warm, food-rich habitats favour species that develop rapidly. Species from warm, shallow, eutrophic ponds develop faster than related species from deep, cold lakes. Sunshine warms favoured habitats of various sorts. For example, shallow water warms up rapidly by solar heating of the bottom and cools down more slowly

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**Table 12.** Sample records of short life cycles in Chalcidoidea.

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| **Mymaridae** | | | | | | |
| *Gonatocerus* sp. | (8.6) | (9.6) | | 8.6 | 30 | Sahad 1982 |
| *Gonatocerus cinctipitis* Sahad | | | 10.15 | | 32 | Miura 1990*b* |
| | (9.3) | | | 8.3 | 32 | Miura 1990*a* |
| *Anaphes listronoti* Huber [not *A. sordidatus* (Girault), see Huber *et al.* 1997] | (9.2) | (10.5) | | 8.7 | 29 | Collins and Grafius 1986 |
| *Anagrus giraulti* Crawford | (10) | | | 9.1 | 32 | Meyerdirk and Moratorio 1987 |
| *Anaphes flavipes* (Foerster) | | | | 7.25 | 32.2 | Anderson and Paschke 1969 |
| | | | | 8.5 | 30 | Anderson and Paschke 1968 |
| **Trichogrammatidae** | | | | | | |
| *Trichogramma chilonis* Ishii | (<8) | | 8.2 | | 28 | Miura and Kobayashi 1995 |
| *Trichogramma pretiosum* Riley | | | 8.4 | | 25 | Pratissoli and Parra 2000 |
| | (6.9) | | 8.6 | 6.8 | 30 | Pak and Oatman 1982*b* |
| | (7.2) | | | 7.2 | 30 | Harrison *et al.* 1985 |
| | (7.7) | | | 6.6 | 32 | Butler and Lopez 1980 |
| | (7.7) | (8.6) | | 7.6 | 32.5 | Naranjo 1993 |
| | 10.2–10.8 | | 12.8 | 9.9 | 25 | Orphanides and Gonzalez 1971 |
| | (11) | (15) | | 10.1 | 25 | Cônsoli and Parra 1996 |
| | | | | 10.4 | 25 | Cônsoli *et al.* 1999 |
| *Trichogramma minutum* Riley | (7) | | | 6.85 | 30 | Yu *et al.* 1984 |
| | (<9) | | 11.7 | (8.0) | 25 | Smith and Hubbes 1986 |
| *Trichogramma exiguum* Pinto and Platner | (7.0) | | | 7.0 | 35 | Harrison *et al.* 1985 |
| *Trichogramma turkestani* Meyer | | | | 7.0 | 30 | Hansen 2000 |
| *Trichogrammatoidea bactrae* Nagaraja | (7.3) | (7.8) | | 7.1 | 30 | Hutchison *et al.* 1990 |
| | (7.4) | (8.3) | | 7.3 | 29.5 | Naranjo 1993 |
| *T. b. fumata* Nagaraja | (9) | (11.5) | | 8.75 | 26.2 | Lim 1986 |
| *Trichogramma evanescens* Westwood | | | | 7.2 | 29.3 | Farghaly 1975 |
| *Trichogramma australicum* Girault | (8) | | | 7.6 | 24, 28 | Dahlan and Gordh 1996, 1998 |
| | (8.7) | | | 7.6 | 28 | Dahlan and Gordh 1996 |

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**Table 12** (*continued*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| | | | | 8.0 | 29 | Jarjees and Merritt 2002 |
| *Trichogramma brevicapillum* Pinto and Platner | (8.6) | | 10.2 | 8.5 | 30 | Pak and Oatman 1982*b* |
| | 10.1 | (11) | | 10 | 25 | Pak and Oatman 1982*a* |
| *Trichogramma papilionis* Nagaraja | | (11?) | | 9 | 25 | Hussein *et al.* 1996 |
| *Trichogramma dendrolimi* Matsumura | 9 | | | 9 | 25 | Takada *et al.* 2000 |
| *Trichogramma* sp. | 9.5 | | | 9.5 | 25 | Stavraki 1976 |
| | (11) | (14.5) | | 11 | 21 | |
| *Trichogramma galloi* Zucchi | (12) | (14) | | 11.3 | 25 | Cônsoli and Parra 1996 |
| | | | | 10.3 | 25 | Cônsoli *et al.* 1999 |
| *Paracentrobia andoi* (Ishii) | (11.5) | | 12.5 | 11.0 | 32 | Miura 1990*c* |
| *Trichogramma retorridum* Girault | 12.4 | | 14.4 | 10.9 | 25 | Orphanides and Gonzalez 1971 |
| **Eulophidae** | | | | | | |
| *Ooencyrtus papilionis* Ashmead | (9.6) | | | 9.1 | 30 | Rahim *et al.* 1991 |
| *Sympiesis marylandensis* Girault | (10) | | | 8.2 | 31 | Ridgway and Mahr 1990 |
| | (13) | (22) | | 10.9 | 23 | |
| *Cirrospilus* sp. nr. *lyncus* | 10.4 | | 12.2 | 8.2 | 30 | Urbaneja *et al.* 1999, 2001 |
| *Edovum puttleri* Grissell [*Euplectrus*] | (12.5) | (16.5?) | | 10 | 30 | Puttler *et al.* 1980 |
| | | | | 11.3 | 29.4 | Obrycki *et al.* 1985 |
| | (14.5?) | | | 11.2 | 29.4 | Ruberson *et al.* 1988, 1989 |
| *Elachertus ceramidiae* Burks | (14) | | | 13 | ? | Harrison 1965 |
| *Oencyrtus trinidadensis* Crawford | (14.2) | | | 14.0 | 28 | Gerling *et al.* 1976 |
| *Cirrospilus vittatus* Walker | (15) | | 19.5 | 12.9 | 30 | Urbaneja *et al.* 2002 |
| *Euplectrus kuwanae* Crawford | (16) | | | 13.3 | 25 | Uematsu 1981*a*, 1981*b* |
| *Pediobius foveolatus* Crawford | | | | 13.5 | 25 | Bledsoe *et al.* 1983 |
| **Aphelinidae** | | | | | | |
| *Aphelinus asychis* (Walker) | | | | 9.5 | 32.2 | Raney *et al.* 1971 |
| *Aphelinus semiflavus* Howard | | | 13.2 | 10.4 | 29.4 | Force and Messenger 1964 |
| *Aphytis lingnanensis* Compere | | | | 10.4 | 32 | Kfir and Luck 1984 |
| *Aphytis melinus* DeBach | | | | 11.0 | 32 | Kfir and Luck 1984 |
| *Aphytis chrysomphali* (Mercet) | | | | 11.3 | 29 | Kfir and Luck 1984 |

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**Table 12** (*concluded*).

| Species | *G* | *O* | *T* | *D* | °C | Reference |
|---|---|---|---|---|---|---|
| *Eretmocerus longipes* Compere | | | | 11.4 | 35 | Sengonca and Liu 1998 |
| *Aphelinus albipodus* (Hayat and Fatima) | | | 15.2 | | 26.7 | Bernal *et al.* 1997 |
| *Encarsia transvena* (Timberlake) | (13.3) | | | 11.3 | 25–30 | Antony *et al.* 2003 |
| *Encarsia pergandiella* Howard | | | | 11.6 | 26.7 | Liu and Stansly 1996 |
| *Aphelinus mali* (Haldeman) | | | | 11.8 | 30 | Asante and Dantharayana 1992 |
| *Aphelinus niger* (Lagace) [*Mesidia nigra*] | (13) | | | 12 | 25.6 | Lagace 1969 |
| *Encarsia deserti* Gerling and Rivnay | (13) | (17) | | 12 | 25 | Gerling *et al.* 1987 |
| *Eretmocerus eremicus* Rose and Zolnerowich | | | | 13.7 | 32 | Greenberg *et al.* 2000 |
| **Elasmidae** | | | | | | |
| *Elasmus broomensis* Naumann and Sands | (13?) | | | 12.4 | 25 | Naumann and Sands 1984 |
| **Pteromalidae** | | | | | | |
| *Anisopteromalus calandrae* (Howard) | 10.4 | | 12.3 | 10.4 | 35 | Smith 1992 |
| | (12) | | 14.6 | 11.45 | 25 | Smith 1993 |
| | 13.6 | | | 12.6 | 28 | Begum 1999 |
| *Amblymerus bruchophagi* (Gahan) | (12.0) | | | 10.5 | 27 | Saunders and Hsiao 1970 |
| *Pteromalus venustus* Walker | (12) | | | 11.2 | 32 | Whitfield and Richards 1985 |
| *Trichomalopsis sarcophagae* Gahan | 12 | | (13.5) | 12 | 30 | Lysyk 1998*b* |
| *Urolepis rufipes* (Ashmead) | (12.5) | (23?) | | 10.5 | 30 | Smith and Rutz 1986 |
| *Eurytoma nesiotes* Crawford | 12.5 | | | 12.5 | ? | Tiwari 1974 |
| *Muscidifurax raptorellus* Kogan and Legner | (13) | | (15) | 12.7 | 30 | Lysyk 2001*b* |
| *Hypopteromalus tabacum* (Fitch) | (13.4) | | | (13) | 27 | McNeil and Rabb 1973 |
| *Catolaccus aeneoviridis* (Girault) | (13.4) | | | (13) | 27 | McNeil and Rabb 1973 |
| *Muscidifurax zaraptor* Kogan and Legner | (14) | | (16) | 13.9 | 30 | Lysyk 2001*a* |
| | 20 | (25.4) | | 19 | 24–28 | Coats 1976 |
| *Rhopalicus tutela* (Walker) | 14.8 | | | 14.8 | 25 | Krüger and Mills 1990 |
| *Catolaccus grandis* (Burks) | 15.1 | | 23.9 | 13.3 | 30 | Morales-Ramos and Cate 1992*b* |
| | | | | 11.8 | 33 | Morales-Ramos and Cate 1993 |
| | | | 18 | | 35 | Morales-Ramos and Cate 1992*a* |
| *Muscidifurax raptor* Girault and Sanders | | | | 10.6 | 32.3 | Ables *et al.* 1976 |

**Note:** Conventions as in Table 1.

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**Table 13.** Sample records of short life cycles in other Hymenoptera.

| Species | *G* | *O* | *D* | °C | Reference |
|---|---|---|---|---|---|
| **Scelionidae** | | | | | |
| *Telenomus reynoldsi* Gordh and Coker | (10?) | | 9.3 | 33 | Cave and Gaylor 1988 |
| *Trissolcus oenone* (Dodd) | (10.7?) | | 9.7 | 30 | James and Warren 1991 |
| *Telenomus triptus* Nixon | (<11) | | 9.0 | 30 | Icuma and Hirose 1996 |
| *Telenomus podisi* Ashmead | (11) | | 10.2 | 29.4 | Yeargan 1980 |
| | (11) | (16) | | 21 | Yeargan 1982 |
| *Gryon gnidus* Nixon | (11) | (12) | 10.5 | 30 | Egwuatu and Taylor 1977 |
| *Gryon clavigrallae* Mineo | 11.5 | (17.5) | 10.5 | 30 | Romeis *et al.* 2000 |
| *Trissolcus semistriatus* (Nees) | (12.5) | | 11.0 | 26 | Kivan and Kilic 2002 |
| *Trissolcus basalis* (Wollaston) | (13) | (15.5) | 10.2 | 27 | Awan *et al.* 1990 |
| | | | 7.8 | 33 | Orr *et al.* 1985 |
| | | | 10 | 32.2 | Powell *et al.* 1981 |
| *Trissolcus mitsukurii* (Ashmead) [*Asolcus*] | (13) | | 12.2 | 25 | Hokyo *et al.* 1966 |
| *Paratelenomus saccharalis* (Dodd) | <13.7 | | 11.7 | 30 | Takagi and Murakami 1997 |
| *Telenomus chloropus* (Thompson) | | | 11.6 | 30 | Orr *et al.* 1985 |
| *Trissolcus euschisti* (Ashmead) | | | 10.2 | 30 | Yeargan 1983 |
| **Bethylidae** | | | | | |
| *Goniozus legneri* Gordh | (10) | | 8.1 | 35 | Butler and Schmidt 1985 |

**Note:** Conventions as in Table 1.

than the air because of the high specific heat of water. Therefore, temperatures above 25 °C can be maintained for long periods in summer even in cool temperate regions. The soil surface and clumps of vegetation also heat up when insolated, leading to temperatures many degrees above ambient even in the Arctic (Corbet 1972). Such conditions allow insects to gain heat through basking and other active behaviours (see Use optimal conditions). Conversely, development in many species from specialized habitats tends to be slow. Typical mosquitoes have relatively rapid larval development, but some species from small container habitats develop slowly; for example, immature stages of a predatory species that lives in bamboo internodes take 25–45 d to develop at 28 °C, and adults oviposit over about 2 months (Okazawa *et al.* 1986). Many habitats are unsuitable for development for large parts of the year when dry summers, cold winters, or limited food prevent rapid development (Danks 1987, 1992).

On a very small scale, habitat influences potential developmental rate by modifying conditions, not only temperature but also various other factors such as humidity and ease of movement. Different leaves with different textures and other properties affect the generation time of mites eating prey on those leaves (El-Banhawy *et al.* 2000).

On a larger scale, the permanence and seasonality of habitats mediate longer-term influences on life-cycle duration. The need for rapid development on ephemeral food sources was noted above. Likewise, species from ephemeral habitats must complete development before those habitats become unsuitable. Macrochelid mites inhabiting dung have short life cycles (*e.g.*, Cicolani 1979). Nevertheless, many such species with rapid larval development do not have short life cycles because the egg stage or adult

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**Table 14.** Families of mites and insects in which species have very short life cycles (for details see Tables 1–13 and text).

| **Acari** |
|---|
| Mesostigmata |
| Phytoseiidae |
| Macrochelidae |
| Ascidae |
| Species in some other families, *e.g.*, Digamasellidae, Laelapidae, Pachylaelapidae |
| Prostigmata |
| Tetranychidae |
| Tarsonemidae |
| Eriophyidae |
| Species in some other families, *e.g.*, Acarophenacidae, Pyemotidae, Pygmephoridae, Cheyletidae, Stigmaeidae |
| Astigmata |
| Acaridae |
| Histiostomatidae |
| Probably at least a few species in many other families in most major groups |
| **Insecta** |
| Hemiptera |
| Aphididae |
| A few species in some other families, *e.g.*, Anthocoridae |
| Diptera |
| Chironomidae |
| Species in some other families of Nematocera, *e.g.*, Culicidae, Ceratopogonidae, Cecidomyiidae |
| A few to several species in some cyclorrhaphan families, *e.g.*, Ephydridae, Drosophilidae |
| Probably a few to several species in many other families |
| Hymenoptera |
| Braconidae |
| Mymaridae |
| Trichogrammatidae |
| Eulophidae |
| Aphelinidae |
| Pteromalidae |
| Scelionidae |
| Species of some other families, *e.g.*, Ichneumonidae, Elasmidae, Bethylidae |
| Probably a few to several species in many other families of Parasitica |

life is prolonged. Snowmelt mosquitoes (*Aedes* spp.) develop rapidly after hatch, before their temporary spring pools evaporate, but the months of winter are spent in the egg stage (Wood *et al.* 1979). Similarly rapid development is known in insects from desert streams (Gray 1981). In many habitats, nest parasites such as cuckoo bees save time by taking over the nests of industrious species (*cf.* Wcislo 1987). Many astigmatic mites are adapted to colonize and develop in scattered and temporally restricted habitats, and these adaptations include faster development (OConnor 1994).

Although long life cycles are seen in parasitoids that remain dormant in a particular stage to wait for host development, other species are subject to a restricted time frame imposed by the limited duration of host suitability, and they develop rapidly. Such parasitoids face challenges of timing because they cannot use the whole host life cycle, because the host itself may develop rapidly, and because competitors may preempt the host tissues. Consequently, many parasitoids, especially on rapidly developing hosts, have fast development (*cf.* Table 12; Sequeira and Mackauer 1992).

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**Table 15.** Summary of potential mechanisms to abbreviate life cycles.

| |
|---|
| **Reduce resources required** |
| Reduce size |
| Reduce fecundity |
| Reduce adult longevity |
| Simplify structures |
| **Eliminate stages** |
| Larvipary |
| Reduced numbers of instars |
| Rapid or non-feeding instars |
| Parthenogenesis |
| Paedogenesis |
| **Accelerate stages** |
| Rapid metabolism |
| Low thresholds and heat requirements |
| Dark colours and hairiness |
| Rapid moulting |
| Group effects |
| Rapid reproduction |
| **Use optimal conditions** |
| Warm habitats or microhabitats |
| Basking |
| Rich food sources |

## Mechanisms for short life cycles

This section summarizes the ways in which the various stages can be abbreviated, using selected examples including some species in which only part, rather than all, of the life cycle is completed very rapidly.

Possible mechanisms to abbreviate life cycles are listed in Table 15, although various constraints limit the degree to which each method is feasible in a given taxon or a given environment. Life cycles are shortened when stages are eliminated or accelerated, a process that is enhanced by reducing resource use, exploiting favourable sites, and minimizing variations in developmental rate.

### Reduce resources required

Reductions in size, fecundity, longevity, and structural complexity all limit the resources, and hence the time, required to complete the life cycle. Both within and between species, smaller individuals require fewer resources and develop faster, other things being equal, as already noted for characteristic families. Thus, smaller species generally develop much more rapidly than their larger relatives (Danks 1978, 1992; Bonner and Horn 1982; Norton 1994).

Less fecund adults need fewer resources, whether these resources are carried through from the larval stage or are acquired in adulthood. For example, data from many species of mites (Sabelis 1991) show that developmental rates are higher when fecundity and oviposition rates are lower. Adults that live for a shorter time, and hence reproduce closer to emergence, likewise tend to require fewer resources. The gall midge *Masakimyia pustulae* Yukawa and Sunose lives for only 6 to 12 h (Sunose 1985), and some mayflies live for only a few hours (*e.g.*, Kureck and Fontes 1996); few insect species that are so short lived as adults feed in that stage. Short life cycles are favoured in such species provided that the larval stages can develop rapidly and food is abundant.

Reducing the complexity of structure conserves energy and hence allows faster development. Wing development provides the best-known examples. In many species with more than one wing form, brachypterous or apterous individuals develop faster than winged ones, even when no ovarian dormancy is correlated with wing form or dispersal. For example, development from birth to adult of most aphids lasts 2 or 3 d less in apterae than in alatae (*e.g.*, Noda 1960; Campbell and Mackauer 1975*a*; Kieckhefer *et al.* 1989). Other species with short wings do not develop especially rapidly but instead devote the resources saved to egg production, as in some lygaeid bugs (Solbreck *et al.* 1990) and in *Orgyia* moths (Lymantriidae) and other species with heavy-bodied wingless females and winged males.

### Eliminate stages

Time can also be saved during development by reducing or eliminating any of the substages of the life cycle, although, of course, such adaptations may relate to protection, dormancy, or other features as well as to possible influences on the rate of development (Danks 2000). Egg stages are eliminated by larvipary, which is relatively widely distributed among the arthropods. At least in aphids, some Diptera, some thrips, and some macrochelid and phytoseiid mites, it contributes to very rapid development. A few specialized species telescope the life cycle even further through development of eggs to the late larval stage within the mother, as in louse flies,

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bat flies, and tsetse flies (Danks 2002*b*). Adult male podapolipid mites hatch directly from the egg (females retain an active larval instar), and in some families (*e.g.*, Pyemotidae) adult females produce adult males and females (Lindquist 1986; Wrensch and Bruce 1991).

Larval stages can be abbreviated by reducing the number of instars and by interpolating rapid, usually non-feeding, instars. The number of juvenile instars has been reduced during the evolution of many different insect and mite groups (*e.g.*, references in Danks 2000, p. 286). In groups with relatively few instars, the first or second instar may also be especially abbreviated, as in some moths, in chironomid midges, and in other insects and mites. Even within a species, the rapid development possible under favourable conditions may take place with fewer instars than slower development under less favourable conditions, as in some species of moths (*e.g.*, Neunzig 1969; Kamata and Igarashi 1995) and spiders (*e.g.*, Miyashita 1997).

The adult stage can be abbreviated by parthenogenesis, which avoids the necessity for mating; moreover, eggs or even larvae can then begin development before adult emergence, as in aphids in which the annual sexual reproduction of overwintering eggs is much slower than the parthenogenetic reproduction by apterae in summer. Indeed, several generations are present in one parthenogenetic female aphid because embryonic development can begin before the mother is born (Uichanco 1924 and later references). In a few species, adults have been eliminated (at least in some generations), and eggs or young are produced by a preadult stage (paedogenesis), further abbreviating the life cycle. The best-known examples are in some fungivorous cecidomyiids, in which larvae of the next generation develop within the mother larva (see references in Table 9). Crowding or exhaustion of available food triggers a switch to the slower sexual cycle, but by preventing these influences up to 250 continuous paedogenetic generations can be reared (Nikolei 1961).

### Accelerate stages

Faster development is assisted by more rapid metabolism (at a given temperature), by reducing the amount of heat required for development, by low threshold temperatures for development, by adaptations of structure or colour to assist heat gains, and in several other ways (Table 15). Many of these adaptations related to temperature are best developed in species from cold environments (reviewed by Danks 1981, 2004), although they occur elsewhere. Apparently, they are not common in warmer habitats partly because such adaptations would be disadvantageous at the upper end of the temperature range.

The thresholds for development and the heat sums (day-degrees) required for development have been studied in many species and stages. Even within a species, stages have different thresholds, so that the speed of development depends on the most demanding link. Although in many species stage-to-stage differences are very small, or only about 2 °C (*e.g.*, *Coleomegilla maculata* (De Geer), egg 10.2 °C, pupa 12.2 °C: Obrycki and Tauber 1978), greater differences are known (*e.g.*, *Cylas formicarius elongatulus* (Summers), egg 9.0 °C, larva 17.4 °C: Mullen 1981).

The average temperature threshold for development in insects is about 10 or 11 °C (Utida 1957; Honěk and Kocourek 1990). Some species from cold habitats and Arctic and alpine zones have much lower developmental thresholds: for example, –1.5 °C for cave-dwelling *Trichocera* spp. (Plachter 1983) and 1 to 2 °C for cold stream stoneflies (Mutch and Pritchard 1986; Økland 1991). Many such species are active at still lower temperatures, even below 0 °C (Jonsson and Sandlund 1975; Aitchison 1983, 1984; Catley 1992; Block *et al.* 1994). Some temperate species have developmental thresholds below 5 °C, including many species of aphids (*e.g.*, Wellings 1981; Lamb 1992), flies (McLeod *et al.* 1985; Kim and Eckenrode 1987), and aquatic species in addition to stoneflies (*e.g.*, 2.5 to 4 °C for chironomids and mayflies: Ohno 1981; Rosillon 1988). Despite these low thresholds, few such species develop very rapidly because their habitats are so cold.

Based on the summaries for 294 mostly temperate species by Honěk and Kocourek (1990), typical species require about 400 day-degrees above the threshold for development from egg to adult, and some require much more, but the lowest requirements, notably in aphids and various parasitic Hymenoptera, are only about 100 or 200 day-degrees for the same interval. For example, the aphidiine braconid *Aphidius ervi* Haliday requires only 73 day-degrees for immature development (Sigsgaard 2000). A generation ($T$) can be completed with only 130.5 day-degrees in the mymarid *Trichogramma minutum* Riley (Lawrence *et al.* 1985) and with

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only 144 day-degrees in the aphid *Myzus persicae* (Sulzer) (Jansson and Smilowitz 1985).

Acquisition of the heat necessary for development is assisted in many species by dark colours and hairiness which, coupled with habitat choice and basking behaviour, enhance and retain heating by the sun. These adaptations are well known in Arctic and alpine species (for reviews see Danks 1981, pp. 266–274; Danks 2004) but are common in temperate species too. Possible overheating at higher temperatures can be partly offset by behaviour. Some species even change colour seasonally, with darker colours in the cooler spring, for example, and lighter colours in summer (Fields and McNeil 1988).

In some species, group effects enhance developmental rate. The "tents" of gregarious caterpillars such as *Malacosoma* species have been supposed to enhance heat gain (see review by Klok and Chown 1999). Some fly larvae raise the temperature and liquify food by group action, making the food more readily available to members of the group (Marchenko and Vinogradova 1984). Other increases in the rate of development depend not on group influences on the habitat but rather on pheromones or on contacts among individuals, as in cockroaches (Nakai and Tsubaki 1986) and some moth larvae (Fitzgerald 1993).

Time might also be saved by reducing the time required for moulting, which in many species occupies a substantial fraction, even as much as half, of the developmental time (Oetting and Yonke 1971; Ayres and MacLean 1987; Ayres and Scriber 1994). Finally, generation time is reduced when reproduction is completed very rapidly. Rapid mating is ensured in many species by protandry (so that males are available upon emergence of females). Some species emerge with eggs fully developed, and many of these do not feed as adults. In other species, females may feed later but lay the first clutch rapidly without feeding (*e.g.*, McLachlan and Yonow 1989 for a chironomid). Even in groups of biting flies well known for developing eggs after the adult feeds on the blood of vertebrate hosts, there are autogenous species that develop eggs more rapidly from larval food reserves.

### Use optimal conditions

Temperatures and food supplies vary from place to place on a wide range of scales and through the season, so that habitat choice greatly influences rates of development. Females of many species oviposit in favourable locations for their offspring, and immature stages may seek out the most favourable sites. Basking behaviour, usually coupled with adaptations of colour and structure, further enhances heat gain, increasing the speed of adult activity or the developmental rate of larvae. Remarkable increases in temperature above ambient temperature can be achieved by melanic, basking individuals such as larvae of the butterfly *Euphydryas aurinia* (Rottemburg), which can reach 30 °C (Porter 1982). More commonly the increases are in the range of 3 to 8 °C (Rawlins and Lederhouse 1981; James 1986), but even so such basking may halve larval developmental time (Rawlins and Lederhouse 1981). The effectiveness of basking depends strongly on size and favours larger individuals (*e.g.*, Bishop and Armbruster 1992); however, very rapid development is less common in large than in small individuals even at high temperatures.

Most species focus active development into a particular part of the year and pass less favourable conditions in a dormant state. Development tends to be especially rapid when the period with the most favourable conditions is very narrow. However, these seasonal adaptations do not necessarily shorten the life cycle as a whole but only promote rapid larval or nymphal development.

## Conclusions

The life cycles of some insects and mites are remarkably short, and some species complete a generation within 1 week. The fastest minimum generation times listed here belong to the histiostomatid mite *Histiostoma polypori* (Oudemans) (3.7 d), the aphid *Aphis glycines* Matsumura (3.9 d), the parasitoid pyemotid mite *Pyemotes tritici* (Lagrèze-Fossat and Montané) (4.0 d), and the predatory phytoseiid mites *Neoseiulus womersleyi* (Schicha) and *N. fallacis* (Garman) (4.0 d). The fastest mean generation times that have been calculated (4.5–5.2 d) belong to four species of predatory *Macrocheles* mites (Macrochelidae).

The species with very fast life cycles come chiefly from a number of families characterized by small species that live in warm climates, habitats, or microhabitats with rich and abundant food. Specific adaptations that favour rapid development include reducing the resources required (by reducing size or fecundity); eliminating life stages, especially instars; accelerating certain stages, especially by physiological

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adaptations; and choosing optimal conditions. The most rapid development is seen in aphids and in certain mites and in some insect parasitoids, all of which are small and have adaptations among those just enumerated. Typical short life cycles thus accord both with intrinsic predisposition through taxonomic affinity and with ecological correlates that can be summarized as a lack of adversity or stress, coupled with physiological and behavioural adaptations for rapid development. Within insects and mites as a whole, therefore, species with very short life cycles are relatively rare.

At the other extreme are species with very long life cycles, even prolonged beyond a year when conditions are cool or unpredictable, food is poor, scattered, or unreliable, individuals are large, and natural enemies are abundant (Danks 1992). Many more species from cool temperate regions have long life cycles typified by univoltinism (Danks and Foottit 1989). Most other species complete a generation relatively rapidly in summer (*e.g.*, between 15 and 45 d, but not more rapidly) but typically much more slowly or not at all in winter. The life-cycle delays in these sorts of species serve to adjust development to ensure seasonal coincidence, especially through control of growth rate, or to withstand adversity, especially through developmental arrests in a resistant stage (Danks 1987, 1994, 2001, 2002*a*). Evidently, these constraints apply to nearly all species, and few species can avoid or overcome them to the extent necessary to complete the life cycle very quickly.

Species with very rapid life cycles belong to two main categories. First, many species living in continuously equable conditions have continuous, overlapped cohorts with very high rates of increase and explosive population growth. A few species reproduce continuously but the cohorts do not overlap. Even in continuously reproducing populations, however, a few individuals may take much longer to complete the life cycle, apparently providing insurance against unpredictability (Danks 1983). Second, species from habitats where conditions are ideal for only a very short time develop in a single burst during the brief suitable period. Although many such species from seasonal habitats are dormant in between these bursts, a few continue to develop rapidly by moving to new habitats that are available all year, including rich but ephemeral sources of dung, carrion, and other decaying materials.

Short life cycles therefore respond to both specific and general forces. Some specific environmental characteristics make rapid development essential: if favourable habitats, food quality, or food supply are restricted, there may be only a short window of opportunity for development. Even when the window is not restricted, however, more rapid development has a simple general demographic advantage: the potential rate of increase of a population depends to the greatest degree on the generation time (Birch 1948; many subsequent papers). Moreover, by limiting the exposure of developing stages to lethal environmental elements, fast development tends to reduce mortality (Cornell 1990, 1991). Given these advantages, in fact, the absence of rapid development in most species is more striking than its presence in a few. Certainly development is constrained: the necessary processes take time and cannot always be telescoped, and many taxa retain all developmental instars. In particular, however, slower development stems from the many constraints present in most environments, notably the seasonality of temperature and resources, as well as their heterogeneity, that force development to follow specific timing and incorporate resistant stages that greatly prolong generation time beyond the theoretical minimum.

Insects and mites with short life cycles are instructive because they provide clues to the complex set of environmental and phylogenetic features that govern the life-cycle traits of a given species. Critical features of timing and resource relationships are brought into focus especially clearly when the life cycle lasts for only a short time. These findings also confirm the remarkable adaptability of the arthropods. Few other taxa encompass a range of generation times from less than 4 days to more than 20 years.

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## References


Aalbersberg, Y.K., and Du Torr, F. 1987. Development rate, fecundity and lifespan of apterae of the Russian wheat aphid, *Diuraphis noxia* (Mordvilko) (Hemiptera: Aphididae), under controlled conditions. Bulletin of Entomological Research, **77**: 629–635.

Abbas, M.S.T., and Abou-Zeid, N.A. 1983. Biological studies on *Bracon instabilis* Marsh. (Hym., Braconidae), a larval parasite of *Phthorimaea operculella* Zell. (Lep., Gelechiidae) in Egypt. Zeitschrift für Angewandte Entomologie, **96**: 32–36.

Abdel-Gawaad, A.A.-W., and El-Shazli, A.Y. 1971. Studies on *Thrips tabaci* Lindman. VII. Effect of food on the life cycle. Zeitschrift für Angewandte Entomologie, **67**: 27–30.

Abdel-Malek, A., Dimetry, N.Z., El-Ziady, S., and El-Hawwary, F.M. 1982. Ecological studies on *Aphis craccivora* Koch. III. The role of day length as an environmental factor regulating development and form produced. Zeitschrift für Angewandte Entomologie, **93**: 238–243.

Ables, J.R., Shepard, M., and Holman, J.R. 1976. Development of the parasitoids *Spalangia endius* and *Muscidifurax raptor* in relation to constant and variable temperature: simulation and validation. Environmental Entomology, **5**: 329–332.

Abou-Awad, B.A. 1980. The biology and morphology of *Eriophyes datura* Soliman and Abou-Awad (Acari: Eriophyoidea: Eriophyidae). Acarologia, **21**: 392–395.

Abou-Awad, B.A. 1981. Bionomics of the mango rust mite *Metaculus mangiferae* (Attiah) with description of immature stages (Eriophyoidea: Eriophyidae). Acarologia, **22**: 151–155.

Abou-Awad, B.A., El-Sherif, A.A., Hassan, M.F., and Abou-Elela, M.M. 1998. Lebensgeschichte und Lebenstafel von *Amblyseius badryi*, einem spezifischen Predator der eriophyiden Grasmilben (Acari: Phytoseiidae: Eriophyidae). Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, **105**: 422–428.

Abou-Awad, B.A., El-Sawaf, B.M., and Abdel-Khalek, A.A. 1999*a*. Impact of two eriophyoid fig mites, *Aceria ficus* and *Rhyncaphytoptus ficifoliae*, as prey on postembryonic development and oviposition rate of the predacious mite *Amblyseius swirskii*. Acarologia, **40**: 367–371.

Abou-Awad, B.A., El-Sawaf, B.M., Reda, A.S., and Abdel-Khalek, A.A. 1999*b*. Environmental management and biological aspects of two eriophyoid fig mites in Egypt: *Aceria ficus* and *Rhyncaphytoptus ficifoliae*. Acarologia, **40**: 419–429.

Abou-Awad, B.A., Korayem, A.M., Hassan, M.F., and Abou-Elela, M.A. 2001. Life history of the predatory mite *Lasioseius athiasae* (Acari, Ascidae) on various kinds of food substances: a polypeptide analysis of prey consideration. Journal of Applied Entomology, **125**: 125–130.

Abou-Setta, M.M., and Childers, C.C. 1989. Biology of *Euseius mesembrinus* (Acari: Phytoseiidae): life tables and feeding behavior on tetranychid mites on citrus. Evironmental Entomology, **18**: 665–669.

Abou-Setta, M.M., and Childers, C.C. 1991. Intrinsic rate of increase over different generation time intervals of insect and mite species with overlapping generations. Annals of the Entomological Society of America, **84**: 517–521.

Aitchison, C.W. 1983. Low temperature and preferred feeding by winter-active Collembola (Insecta, Apterygota). Pedobiologia, **25**: 27–36.

Aitchison, C.W. 1984. Low temperature feeding by winter-active spiders. Journal of Arachnology, **12**: 297–305.

Aldyhim, Y.N., and Khalil, A.F. 1993. Influence of temperature and daylength on population development of *Aphis gossypii* on *Cucurbita pepo*. Entomologia Experimentalis et Applicata, **67**: 167–172.

Ali, F.S. 1998. Life tables of *Phytoseiulus macropilis* (Banks) (Gamasida: Phytoseiidae) at different temperatures. Experimental and Applied Acarology, **22**: 335–342.

Allen, J.C., Yang, Y., and Knapp, J.L. 1995. Temperature effects on development and fecundity of the citrus rust mite (Acari: Eriophyidae). Environmental Entomology, **24**: 996–1004.

Allingham, P.G. 1991. Effect of temperature on late immature stages of *Culicoides brevitarsis* (Diptera: Ceratopogonidae). Journal of Medical Entomology, **28**: 878–881.

Altahtawy, M.M., Hammad, S.M., and Hegazi, E.M. 1976. Studies on the dependence of *Microplitis rufiventris* Kok. (Hym., Braconidae) parasitizing *Spodoptera littoralis* (Boisd.) on own food as well as on food of its host. Zeitschrift für Angewandte Entomologie, **81**: 3–13.

Amano, H., and Chant, D.A. 1977. Life history and reproduction of two species of predacious mites, *Phytoseiulus persimilis* Athias-Henriot and *Amblyseius andersoni* (Chant) (Acarina: Phytoseiidae). Canadian Journal of Zoology, **55**: 1978–1983.

Anderson, R.C., and Paschke, J.D. 1968. The biology and ecology of *Anaphes flavipes* (Hymenoptera: Mymaridae), an exotic egg parasite of the cereal leaf beetle. Annals of the Entomological Society of America, **61**: 1–5.

Anderson, R.C., and Paschke, J.D. 1969. Additional observations on the biology of *Anaphes flavipes* (Hymenoptera: Mymaridae), with special reference to the effects of temperature and superparasitism on development. Annals of the Entomological Society of America, **62**: 1316–1321.

Antony, B., Palaniswami, M.S., and Henneberry, T.J. 2003. *Encarsia transvena* (Hymenoptera: Aphelinidae) development on different *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) instars. Environmental Entomology, **32**: 584–591.


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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Arbabi, M., and Baradaran, P. 2001. Study on population fluctuation of *Amblydromella kettanehi* Denmark and Daaeshvar on *Pinus eldarica* Medw. in Tehran and its biology on *Tetranychus urticae* Koch under laboratory condition. Journal of Entomological Society of Iran, **20**: 1–21. [In Farsi.]

Asante, S.K., and Danthanarayana, W. 1992. Development of *Aphelinus mali* an endoparasitoid of woolly apple aphid, *Eriosoma lanigerum* at different temperatures. Entomologia Experimentalis et Applicata, **65**: 31–37.

Ash, N., and Greenberg, B. 1975. Developmental temperature responses of the sibling species *Phaenicia sericata* and *Phaenicia pallescens*. Annals of the Entomological Society of America, **68**: 197–200.

Ashihara, W. 1987. Infestation and reproduction of the citrus red mite, *Panonychus citri* (McGregor) (Acarina: Tetranychidae) on leguminous plants. Applied Entomology and Zoology, **22**: 512–518.

Asin, L., and Pons, X. 2001. Effect of high temperature on the growth and reproduction of corn aphids (Homoptera: Aphididae) and implications for their population dynamics on the northeastern Iberian peninsula. Environmental Entomology, **30**: 1127–1134.

Askari, A., and Stern, V.M. 1972. Biology and feeding habits of *Orius tristicolor* (Hemiptera: Anthocoridae). Annals of the Entomological Society of America, **65**: 96–100.

Attiah, H.H., Hanna, M.A., Rizk, R.A., and El-Saadany, G. 1978. Species differences between *Tetranychus cucurbitacearum* (Say.) and *T. arabicus* At. in response to rearing humidity. Zeitschrift für Angewandte Entomologie, **85**: 37–42.

Awan, M.S., Wilson, L.T., and Hoffmann, M.P. 1990. Comparative biology of three geographic populations of *Trissolcus basalis* (Hymenoptera: Scelionidae). Environmental Entomology, **19**: 387–392.

Ayres, M.P., and MacLean, S.F., Jr. 1987. Molt as a component of insect development: *Galerucella sagittariae* (Chrysomelidae) and *Epirrita autumnata* (Geometridae). Oikos, **48**: 273–279.

Ayres, M.P., and Scriber, J.M. 1994. Local adaptation to regional climates in *Papilio canadensis* (Lepidoptera: Papilionidae). Ecological Monographs, **64**: 465–482.

Badii, M.H., and McMurtry, J.A. 1984. Life history of and life table parameters for *Phytoseiulus longipes* with comparative studies on *P. persimilis* and *Typhlodromus occidentalis* (Acari: Phytoseiidae). Acarologia, **25**: 111–123.

Bakker, K., and Nelissen, F.X. 1963. On the relations between the duration of the larval and pupal period, weight and diurnal rhythm in emergence in *Drosophila melanogaster*. Entomologia Experimentalis et Applicata, **6**: 37–52.

Ball, J.C. 1980. Development, fecundity, and prey consumption of four species of predacious mites (Phytoseiidae) at two constant temperatures. Environmental Entomology, **9**: 298–303.

Ballou, J.K., Tsai, J.H., and Center, T.D. 1986. Effects of temperature on the development, natality, and longevity of *Rhopalosiphum nymphaeae* (L.) (Homoptera: Aphididae). Environmental Entomology, **15**: 1096–1099.

Barker, P.S. 1967. The effects of high humidity and different temperatures on the biology of *Tyrophagus putrescentiae* (Schrank) (Acarina: Tyrogliphidae). Canadian Journal of Zoology, **45**: 91–96.

Barker, P.S. 1974. Bionomics of *Caloglyphus anomalus* Nesbitt (Acarina: Acaridae). The Manitoba Entomologist, **8**: 41–47.

Barnard, D.R., and Jones, R.H. 1980. *Culicoides variipennis*: seasonal abundance, overwintering, and voltinism in northeastern Colorado. Environmental Entomology, **9**: 709–712.

Basha, A.E., Yousef, A.A., and Mostafa, E.M. 2002. Morphology and biology of *Euseius metwallyi* n. sp. (Acari: Gamasida: Phytoseiidae). Acarologia, **42**: 29–37.

Baumann, R.W. 1987. Order Plecoptera. *In* Immature insects. *Edited by* F.W. Stehr. Kendall/Hunt, Dubuque, Iowa. pp. 186–195.

Baumgartner, D.L. 1993. Review of *Chrysomya rufifacies* (Diptera: Calliphoridae). Journal of Medical Entomology, **30**: 338–352.

Baxendale, F.P., Teetes, G.L., Sharpe, P.J.H., and Wu, H. 1984. Temperature-dependent model for development of nondiapausing sorghum midges (Diptera: Cecidomyiidae). Environmental Entomology, **13**: 1572–1576.

Beavers, J.B., and Hampton, R.B. 1971. Growth, development, and mating behavior of the citrus red mite (Acarina: Tetranychidae). Annals of the Entomological Society of America, **64**: 804–806.

Begum, S. 1999. Biology of the parasitoid, *Anisopteromalus calandrae* How. (Hymenoptera: Pteromalidae). Bangladesh Journal of Zoology, **27**: 125–129.

Behura, B.K. 1957. The life-history of *Histiostoma polypori* (Oud.) (Acari: Tyroglyphoidea). Journal of the New York Entomological Society, **65**: 51–78.

Bergh, J.C. 1994. Pear rust mite (Acari: Eriophyidae) fecundity and development at constant temperatures. Environmental Entomology, **23**: 420–424.

Bernal, J.S., Waggoner, M., and González, D. 1997. Reproduction of *Aphelinus albipodus* (Hymenoptera: Aphelinidae) on Russian wheat aphid (Hemiptera: Aphididae) hosts. European Journal of Entomology, **94**: 83–96.

Biever, K.D. 1965. A rearing technique for the colonization of chironomid midges. Annals of the Entomological Society of America, **58**: 135–136.

Birch, L.C. 1948. The intrinsic rate of natural increase of an insect population. Journal of Animal Ecology, **17**: 15–26.

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Bishop, J.A., and Armbruster, W.S. 1992. The relationship between size and thermoregulatory capability in social and solitary bees of interior Alaska. Bulletin of the Ecological Society of America, **73**: 112.

Bishop, A.L., McKenzie, H.J., Barchia, I.M., and Harris, A.M. 1996. Effect of temperature regimes on the development, survival and emergence of *Culicoides brevitarsis* Kieffer (Diptera: Ceratopogonidae) in bovine dung. Australian Journal of Entomology, **35**: 361–368.

Bledsoe, L.W., Flanders, R.V., and Edwards, C.R. 1983. Morphology and development of the immature stages of *Pediobius foveolatus* (Hymenoptera: Eulophidae). Annals of the Entomological Society of America, **76**: 953–957.

Bliss, M., Jr., and Kearby, W.H. 1971. Observations on the oviposition sites and laboratory development of the fundatrix and virginopara of the aphid *Eulachnus agilis*. Annals of the Entomological Society of America, **64**: 1407–1410.

Block, W., Webb, N.R., Coulson, S., Hodkinson, I.D., and Worland, M.R. 1994. Thermal adaptation in the Arctic collembolan *Onychiurus arcticus* (Tullberg). Journal of Insect Physiology, **40**: 715–722.

Bloem, K.A., and Duffey, S.S. 1990. Effect of protein type and quantity on growth and development of larval *Heliothis zea* and *Spodoptera exigua* and the endoparasitoid *Hyposoter exiguae*. Entomologia Experimentalis et Applicata, **54**: 141–148.

Blommers, L. 1974. Preliminary studies on two predators (Acarina: Phytoseiidae) of the spider mite *Tetranychus neocaledonicus* André (Acarina: Tetranychidae). Zeitschrift für Angewandte Entomologie, **75**: 315–321.

Blommers, L. 1976. Capacities for increase and predation in *Amblyseius bibens* (Acarina: Phytoseiidae). Zeitschrift für Angewandte Entomologie, **81**: 225–244.

Boling, J.C., and Pitre, H.N. 1970. Life history of *Apanteles marginiventris* with descriptions of immature stages. Journal of the Kansas Entomological Society, **43**: 465–470.

Bonato, O., Mapangou-Divassa, S., and Gutierrez, J. 1995. Influence of relative humidity on life-history parameters of *Mononychellus progresivus* and *Oligonychus gossypii* (Acari: Tetranychidae). Environmental Entomology, **24**: 841–845.

Bonner, J.T., and Horn, H.S. 1982. Selection for size, shape, and development timing. *In* Evolution and development: Report of the Dahlem workshop on evolution and development, Berlin, 10–15 May 1981. *Edited by* J.T. Bonner. Springer-Verlag, Berlin. pp. 259–276.

Boorman, J. 1974. The maintenance of laboratory colonies of *Culicoides variipennis* (Coq.), *C. nubeculosus* (Mg.) and *C. riethi* Kieff. (Diptera, Ceratopogonidae). Bulletin of Entomological Research, **64**: 371–377.

Bounfour, M., and Tanigoshi, L.K. 2001. Effect of temperature on development and demographic parameters of *Tetranychus urticae* and *Eotetranychus carpini borealis* (Acari: Tetranychidae). Annals of the Entomological Society of America, **94**: 400–404.

Boyne, J.V., and Hain, F.P. 1983*a*. Effects of constant temperature, relative humidity, and simulated rainfall on development and survival of the spruce spider mite (*Oligonychus ununguis*). The Canadian Entomologist, **115**: 93–105.

Boyne, J.V., and Hain, F.P. 1983*b*. Responses of *Neoseiulus fallacis* (Acarina: Phytoseiidae) to different prey densities of *Oligonychus ununguis* (Acarina: Tetranychidae) and to different relative humidity regimes. The Canadian Entomologist, **115**: 1607–1614.

Branson, T.F., and Ortman, E.E. 1967. Biology of laboratory-reared corn leaf aphids, *Rhopalosiphum maidis* (Homoptera: Aphididae). Annals of the Entomological Society of America, **60**: 1118–1119.

Brittain, J.E. 1982. Biology of mayflies. Annual Review of Entomology, **27**: 119–147.

Brooks, H.L., and Warren, L.O. 1964. Biology of a pine bark aphid, *Cinara watsoni*, and its response to temperature. Journal of the Kansas Entomological Society, **37**: 310–316.

Broufas, G.D., and Koveos, D.S. 2000. Effect of different pollens on development, survivorship and reproduction of *Euseius finlandicus* (Acari: Phytoseiidae). Environmental Entomology, **29**: 743–749.

Broufas, G.D., and Koveos, D.S. 2001. Development, survival and reproduction of *Euseius finlandicus* (Acari: Phytoseiidae) at different constant temperatures. Experimental and Applied Acarology, **25**: 441–460.

Brown, H.D. 1972. On the biology of *Lioadalia flavomaculata* (Deg.) (Col., Coccinellidae), a predator of the wheat aphid (*Schizaphis graminum* (Rond.)) in South Africa. Bulletin of Entomological Research, **61**: 673–679.

Browning, H.W., and Oatman, E.R. 1981. Effects of different constant temperatures on adult longevity, development time, and progeny production of *Hyposoter exiguae* (Hymenoptera: Ichneumonidae). Annals of the Entomological Society of America, **74**: 79–82.

Browning, H.W., and Oatman, E.R. 1985. Reproductive biology of *Microplitis brassicae* (Hymenoptera: Braconidae), parasite of the cabbage looper, *Trichoplusia ni* (Lepidoptera: Noctuidae). Annals of the Entomological Society of America, **78**: 369–372.

Bruce, W.A. 1984. Temperature and humidity: effects on survival and fecundity of *Pyemotes tritici* (Acari: Pyemotidae). International Journal of Acarology, **10**: 135–138.

Buckingham, G.R., and Bennett, C.A. 1981. Laboratory biology and behavior of *Litodactylus leucogaster*, a ceutorhynchine weevil that feeds on

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

watermilfoils. Annals of the Entomological Society of America, **74**: 451–458.

Butler, G.D., Jr., and Lopez, J.D. 1980. *Trichogramma pretiosum*: development in two hosts in relation to constant and fluctuating temperatures. Annals of the Entomological Society of America, **73**: 671–673.

Butler, G.D., Jr., and Schmidt, K.M. 1985. *Goniozus legneri* (Hymenoptera: Bethylidae): development, oviposition, and longevity in relation to temperature. Annals of the Entomological Society of America, **78**: 373–375.

Byrd, J.H., and Allen, J.C. 2001. The development of the black blow fly, *Phormia regina* (Meigen). Forensic Science International, **120**: 79–88.

Byrd, J.H., and Butler, J.F. 1997. Effects of temperature on *Chrysomya rufifacies* (Diptera: Calliphoridae) development. Journal of Medical Entomology, **34**: 353–358.

Caceres, S., and Childers, C.C. 1991. Biology and life tables of *Galendromus helveolus* (Acari: Phytoseiidae) on Florida citrus. Environmental Entomology, **20**: 224–229.

Campbell, A., and Mackauer, M. 1975*a*. Thermal constants for development of the pea aphid (Homoptera: Aphididae) and some of its parasites. The Canadian Entomologist, **107**: 419–423.

Campbell, A., and Mackauer, M. 1975*b*. The effect of parasitism by *Aphidius smithi* (Hymenoptera: Aphidiidae) on reproduction and population growth of the pea aphid (Homoptera: Aphididae). The Canadian Entomologist, **107**: 919–926.

Campbell, A., and Mackauer, M. 1977. Reproduction and population growth of the pea aphid (Homoptera: Aphididae) under laboratory and field conditions. The Canadian Entomologist, **109**: 277–284.

Campbell, C.D., and Hutchison, W.D. 1995. Rearing methods and demographic statistics for a subterranean morph of the sugarbeet root aphid (Homoptera: Aphididae). The Canadian Entomologist, **127**: 65–77.

Camporese, P., and Duso, C. 1995. Life history and life table parameters of the predatory mite *Typhlodromus talbii*. Entomologia Experimentalis et Applicata, **77**: 149–157.

Cannon, R.J.C. 1984. The development rate of *Metopolophium dirhodum* (Walker) (Hemiptera: Aphidide) on winter wheat. Bulletin of Entomological Research, **74**: 33–46.

Capinera, J.L., Narango, S.E., and Renaud, A.R. 1981. Alfalfa webworm: larval development in response to diet and temperature. Southwest Entomologist, **6**: 10–17.

Caresche, L.A., and Wapshere, A.J. 1975. The *Chondrilla* gall midge, *Cystiphora schmidti* (Rübsaamen) (Diptera, Cecidomyiidae). II. Biology and host specificity. Bulletin of Entomological Research, **65**: 55–64.

Carey, J.R. 1993. Applied demography for biologists with special emphasis on insects. Oxford University Press, New York.

Carey, J.R., and Bradley, J.W. 1982. Developmental rates, vital schedules, sex ratios, and life tables for *Tetranychus urticae*, *T. turkestani* and *T. pacificus* (Acarina: Tetranychidae) on cotton. Acarologia, **23**: 333–345.

Carroll, D.P., and Hoyt, S.C. 1986*a*. Developmental rate, weight, and ovarian parameters of apple aphids, *Aphis pomi* (Homoptera: Aphididae), reared at one or two constant temperatures, with evidence of residual effects. Environmental Entomology, **15**: 607–613.

Carroll, D.P., and Hoyt, S.C. 1986*b*. Some effects of parental rearing conditions and age on progeny birth weight, growth, development, and reproduction in the apple aphid, *Aphis pomi* (Homoptera: Aphididae). Environmental Entomology, **15**: 614–619.

Cartier, J.J. 1960. Growth, reproduction and longevity in one biotype of the pea aphid, *Acyrthosiphon pisum* (Harr.) (Homoptera: Aphididae). The Canadian Entomologist, **92**: 762–764.

Castagnoli, M., and Liguori, M. 1986. Tempi di sviluppo e ovideposizione di *Typhlodromus exhilaratus* Ragusa (Acarina: Phytoseiidae) allevato con vari tipi di cibo. Redia, **69**: 361–368.

Castagnoli, M., Amato, F., and Monagheddu, M. 1989. Osservazioni biologiche e parametri demografici di *Eotetranychus carpini* (Oud.) (Acarina: Tetranychidae) e del suo predatore *Typhlodromus exhilaratus* Ragusa (Acarina: Phytoseiidae) in condizioni di laboratorio. Redia, **72**: 545–557.

Catley, K.M. 1992. Supercooling and its ecological implications in *Coelotes atropos* (Araneae, Agelenidae). Journal of Arachnology, **20**: 58–63.

Cave, R.D., and Gaylor, M.J. 1988. Influence of temperature and humidity on development and survival of *Telenomus reynoldsi* (Hymenoptera: Scelionidae) parasitizing *Geocoris punctipes* (Heteroptera: Lygaeidae) eggs. Annals of the Entomological Society of America, **81**: 278–285.

Childs, G.H., Ashley, T.R., Habeck, D.H., and Poe, S.L. 1984. Temperature effects on development and reproduction of the southern red mite, *Oligonychus ilicis*, reared on *Ilex crenata*. Acarologia, **25**: 341–345.

Chippindale, A.K., Alipaz, J.A., Chen, H.-W., and Rose, M.R. 1997. Experimental evolution of accelerated development in *Drosophila.* I. Developmental speed and larval survival. Evolution, **51**: 1536–1551.

Cicolani, B. 1978. The influence of temperature on the speed of development, from egg to adult, of *Macrocheles matrius* (Acarina: Mesostigmata). Acarologia, **19**: 384–394.

Cicolani, B. 1979. The intrinsic rate of natural increase in dung macrochelid mites, predators of *Musca domestica* eggs. Bolletino di Zoologia, **46**: 171–178.

Cicolani, B. 1983. Action de différentes températures constantes sur la durée de développement, de l'œuf

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à l'adulte, des macrochélides fimicoles *Macrocheles subbadius* et *Macrocheles vernalis* (Acarina: Mesostigmata). Acarologia, **24**: 145–158.

Cicolani, B., Passariello, S., and Petrelli, G. 1977. Influenza della temperatura su l'incremento di populazione in *Macrocheles subbadius* (Acarina: Mesostigmata). Acarologia, **19**: 563–578.

Coats, S.A. 1976. Life cycle and behaviour of *Muscidifurax zaraptor* (Hymenoptera: Pteromalidae). Annals of the Entomological Society of America, **69**: 772–780.

Cocuzza, G.E., De Clercq, P., Lizzio, S., Van de Veire, M., Tirry, L., Degheele, D., and Vacante, V. 1997. Life tables and predation activity of *Orius laevigatus* and *O. albidipennis* at three constant temperatures. Entomologia Experimentalis et Applicata, **85**: 189–198.

Cohen, M.B., and Mackauer, M. 1987. Intrinsic rate of increase and temperature coefficients of the aphid parasite *Ephedrus californicus* Baker (Hymenoptera: Aphidiidae). The Canadian Entomologist, **119**: 231–237.

Collins, R.D., and Grafius, E. 1986. Biology and life cycle of *Anaphes sordidatus* (Hymenoptera: Mymaridae), an egg parasitoid of the carrot weevil (Coleoptera: Curculionidae). Environmental Entomology, **15**: 100–105.

Colwell, R.K. 1973. Competition and coexistence in a simple tropical community. American Naturalist, **107**: 737–760.

Congdon, B.D., and Logan, J.A. 1983. Temperature effects on development and fecundity of *Oligonychus pratensis* (Acari: Tetranychidae). Environmental Entomology, **12**: 359–362.

Connell, T.D., and Scheiring, J.F. 1982. Demography of the shore fly, *Scatella picea* (Walker) (Diptera: Ephydridae). Environmental Entomology, **11**: 611–617.

Cônsoli, F.L., and Parra, J.R.P. 1996. Biology of *Trichogramma galloi* and *T. pretiosum* (Hymenoptera: Trichogrammatidae) reared *in vitro* and *in vivo*. Annals of the Entomological Society of America, **89**: 828–834.

Cônsoli, F.L., Rossi, M.M., and Parra, J.R.P. 1999. Developmental time and characteristics of the immature stages of *Trichogramma galloi* and *T. pretiosum* (Hymenoptera, Trichogrammatidae). Revista Brasileira de Entomologia, **43**: 271–275.

Cônsoli, R.A.G.B., and Williams, P. 1978. Laboratory observations on the bionomics of *Aedes fluviatilis* (Lutz) (Diptera: Culicidae). Bulletin of Entomological Research, **68**: 123–136.

Corbet, P.S. 1972. The microclimate of arctic plants and animals, on land and in fresh water. Acta Arctica, **18**: 1–43.

Corbet, P.S., and Danks, H.V. 1975. Egg-laying habits of mosquitoes in the high arctic. Mosquito News, **35**: 8–14.

Cornell, H.V. 1990. Survivorship, life history and concealment: a comparison of leaf miners and gall formers. American Naturalist, **136**: 581–597.

Cornell, H.V. 1991. Survivorship, life history, and concealment: a comparison of leaf miners and gall formers. Bulletin of the Ecological Society of America, **72**: 92.

Coville, P.L., and Allen, W.W. 1977. Life table and feeding habits of *Scolothrips sexmaculatus* (Thysanoptera: Thripidae). Annals of the Entomological Society of America, **70**: 11–16.

Cross, E.A., and Bohart, G.E. 1990. Notes on the life history of *Sancassania boharti* (Acari: Acaridae) and its relationship to the alkali bee, *Nomia melanderi* (Hymenoptera: Halictidae). Journal of the Kansas Entomological Society, **63**: 603–610.

Cross, E.A., and Kaliszewski, M.J. 1988. The life history of a mushroom pest mite, *Pediculaster flechtmanni* (Wicht) (Acari: Pygmephoroidea), with studies of alternate morph formation. Environmental Entomology, **17**: 309–315.

Dahlan, A.N., and Gordh, G. 1996. Development of *Trichogramma australicum* Girault (Hymenoptera: Trichogrammatidae) on *Helicoverpa armigera* (Hübner) eggs (Lepidoptera: Noctuidae). Australian Journal of Entomology, **35**: 337–344.

Dahlan, A.N., and Gordh, G. 1998. Development of *Trichogramma australicum* Girault (Hymenoptera: Trichogrammatidae) in eggs of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) and in artificial diet. Australian Journal of Entomology, **37**: 254–264.

Danks, H.V. 1978. Some effects of photoperiod, temperature and food on emergence in three species of Chironomidae (Diptera). The Canadian Entomologist, **110**: 289–300.

Danks, H.V. 1981. The composition, distribution and ecology of arctic insects, with some speculations on the evolution of arctic communities. *In* Evolution today. Proceedings of the 2nd International Congress of Systematic and Evolutionary Biology, Vancouver, British Columbia, 17–24 July 1980. *Edited by* G.G.E. Scudder and J.L. Reveal. Hunt Institute of Botanical Documentation, Pittsburgh, Pennsylvania. pp. 21–23.

Danks, H.V. 1983. Extreme individuals in natural populations. Bulletin of the Entomological Society of America, **29**: 41–46.

Danks, H.V. 1987. Insect dormancy: an ecological perspective. Biological Survey of Canada (Terrestrial Arthropods), Ottawa, Ontario.

Danks, H.V. 1992. Long life cycles in insects. The Canadian Entomologist, **124**: 167–187.

Danks, H.V. 1994. Diversity and integration of life-cycle controls in insects. *In* Insect life-cycle polymorphism: theory, evolution and ecological consequences for seasonality and diapause control. *Edited by* H.V. Danks. Kluwer Academic Publishers, Dordrecht. pp. 5–40.

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Danks, H.V. 2000. Measuring and reporting life-cycle duration in insects and arachnids. European Journal of Entomology, **97**: 285–303.

Danks, H.V. 2001. The nature of dormancy responses in insects. Acta Societatis Zoologicae Bohemicae, **65**: 169–179.

Danks, H.V. 2002*a*. The range of insect dormancy responses. European Journal of Entomology, **99**: 127–142.

Danks, H.V. 2002*b*. Modification of adverse conditions by insects. Oikos, **99**: 10–24.

Danks, H.V. 2004. Seasonal adaptations in arctic insects. Integrative and Comparative Biology, **44**: 85–94.

Danks, H.V., and Foottit, R.G. 1989. Insects of the boreal zone of Canada. The Canadian Entomologist, **121**: 626–677.

Darst, P.H., and King, E.W. 1969. Biology of *Melichares tarsalis* in association with *Plodia interpunctella*. Annals of the Entomological Society of America, **62**: 747–749.

Das, G.M., and Das, S.C. 1966. Effect of temperature and humidity on the development of tea red spider mite, *Oligonychus coffeae* (Nietner). Bulletin of Entomological Research, **57**: 433–436.

Davis, R., and Hunter, P.E. 1963. Biological studies of a *Histiogaster* mite (Acarina: Acaridae) associated with pine reproduction weevils. Annals of the Entomological Society of America, **56**: 682–687.

de Moraes, G.J., and Lima, H.C. 1983. Biology of *Euseius concordis* (Chant) (Acarina: Phytoseiidae) a predator of the tomato russet mite. Acarologia, **24**: 251–255.

de Moraes, G.J., and McMurtry, J.A. 1981. Biology of *Amblyseius citrifolius* (Denmark and Muma) (Acarina: Phytoseiidae). Hilgardia, **49**: 1–29.

de Moraes, G.J., McMurtry, J.A., and Denmark, H.A. 1986. A catalog of the mite family Phytoseiidae: references to taxonomy, synonymy, distribution and habitat. Embrapa-DDT, Brasilia.

Dean, G.J. 1974. Effect of temperature on the cereal aphids *Metopolophium dirhodum* (Wlk.), *Rhopalosiphum padi* (L.) and *Macrosiphum avenae* (F.) (Hem., Aphididae). Bulletin of Entomological Research, **63**: 401–409.

Debolt, J.W. 1981. Laboratory biology and rearing of *Leiophron uniformis* (Gahan) (Hymenoptera: Braconidae), a parasite of *Lygus* spp. (Hemiptera: Miridae). Annals of the Entomological Society of America, **74**: 334–337.

Dejoux, C. 1971. Recherches sur le cycle de développement de *Chironomus pulcher* (Diptera: Chironomidae). The Canadian Entomologist, **103**: 465–470.

Depner, K.R. 1961. The effect of temperature on development and diapause of the horn fly, *Siphona irritans* (L.) (Diptera: Muscidae). The Canadian Entomologist, **93**: 855–859.

Dinh, N.V., Janssen, A., and Sabelis, M.W. 1988. Reproductive success of *Amblyseius idaeus* and *A. anonymus* on a diet of two-spotted spider mites. Experimental and Applied Acarology, **4**: 41–51.

Eggers-Schumacher, H.A. 1983. A comparison of the reproductive performance of insecticide-resistant and susceptible clones of *Myzus persicae*. Entomologia Experimentalis et Applicata, **34**: 301–307.

Egwuatu, R.I., and Taylor, T.A. 1977. Bionomics of *Gyron gnidus* Nixon (Hymenoptera: Scelionidae), an egg parasite of *Acanthomia tomentosicollis* Stål (Hemiptera: Coreidae) in Nigeria. Applied Entomology and Zoology, **12**: 76–78.

El-Banhawy, E.M., Amer, S.A.A, and Saber, S.A. 2000. Development and reproduction of the predacious mite, *Amblyseius cydnodactylon* on different prey species; effect of plant leaf texture on the behaviour and reproduction of the predator. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, **107**: 218–224.

El Din, N.S. 1976. Effects of temperature on the aphid, *Myzus persicae* (Sulz.), with special reference to critically low and high temperature. Zeitschrift für Angewandte Entomologie, **80**: 7–14.

El-Laithy, A.Y.M., and Fouly, A.H. 1992. Life table parameters of the two phytoseiid predators *Amblyseius scutalis* (Athias-Henriot) and *A. swirskii* A.-H. (Acari, Phytoseiidae) in Egypt. Journal of Applied Entomology, **113**: 8–12.

Elbadry, E.A., and Tawfik, M.S.F. 1966. Life cycle of the mite *Adactylidium* sp. (Acarina: Pyemotidae), a predator of thrips eggs in the United Arab Republic. Annals of the Entomological Society of America, **59**: 458–461.

Elliott, N.C., and Kieckhefer, R.W. 1989. Effects of constant and fluctuating temperatures on immature development and age-specific life tables of *Rhopalosiphum padi* (L.) (Homoptera: Aphididae). The Canadian Entomologist, **121**: 131–140.

Engroff, B.W., and Watson, T.F. 1975. Influence of temperature on adult biology and population growth of *Bracon kirkpatricki*. Annals of the Entomological Society of America, **68**: 1121–1125.

Farghaly, H.T. 1975. Some bionomic dates on the parasite *Trichogramma evanescens* Westwood in the eggs of *Anagasta kuehniella* Zeller. Zeitschrift für Angewandte Entomologie, **79**: 332–335.

Fay, H.A.C. 1985. Temperature-regulated development rates of the immature stages of the African buffalo fly, *Haematobia thirouxi potans* (Bezzi) (Diptera: Muscidae). Environmental Entomology, **14**: 38–41.

Feldmann, A.M. 1981. Life table and male mating competitiveness of wild type and of a chromosome mutation strain of *Tetranychus urticae* in relation to genetic pest control. Entomologia Experimentalis et Applicata, **29**: 125–137.

Fereres, A., Lister, R.M., Araya, J.E., and Foster, J.E. 1989. Development and reproduction of the English grain aphid (Homoptera: Aphididae) on wheat cultivars infected with barley yellow dwarf virus. Environmental Entomology, **18**: 388–393.

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Fernandez-Quintanilla, C., Fereres, A., Godfrey, L., and Norris, R.F. 2002. Development and reproduction of *Myzus persicae* and *Aphis fabae* (Hom., Aphididae) on selected weed species surrounding sugar beet fields. Journal of Applied Entomology, **126**: 198–202.

Ferragut, F., Garci-Marí, F., Costa-Comelles, J., and Laborda, R. 1987. Influence of food and temperature on development and oviposition of *Euseius stipulatus* and *Typhlodromus phialatus* (Acari: Phytoseiidae). Experimental and Applied Acarology, **3**: 317–329.

Fields, P.G., and McNeil, J.N. 1988. The importance of seasonal variation in hair coloration for thermoregulation of *Ctenucha virginica* larvae (Lepidoptera: Arctiidae). Physiological Entomology, **13**: 165–175.

Filipponi, A., and Cicolani, B. 1974. Influenza della temperatura sulla fecondità, longevità e capacità moltiplicativa nell'intervallo ottimale di *Macrocheles matrius* (Acarina : Mesostigmata). Rivista di Parassitologia, **35**: 291–306.

Filipponi, A., and Mosna, B. 1968. Influenza di fattori ecologici e genetici sulla natalità e mortalità di *Macrocheles robustulus* (Berlese, 1904). Annali dell Istituto Superiore di Sanità, **4**: 551–571.

Filipponi, A., and Passariello, S. 1969. Influenza della temperatura sulla fecondità, longevità e capacità moltiplicativa di *Macrocheles peniculatus* Berlese (Acarina, Mesostigmata). Rivista di Parassitologia, **30**: 259–310.

Filipponi, A., and Petrelli, G. 1969. Sulla capacità moltiplicativa di *Macrocheles perglaber* (Acarina, Mesostigmata) in condizioni di laboratorio. Parassitologia, **11**: 1–4.

Filipponi, A., Mosma, B., and Petrelli, G. 1971*a*. L'ottimo di temperatura di *M. muscaedomesticae* (Scopoli) (Acarina: Mesostigmata). Rivista di Parassitologia, **28**: 129–156.

Filipponi, A., Petrelli, G., and Passariello, S. 1971*b*. Contributi sperimentali di laboratoria sulla autoecologia e demoecologia di *Macrocheles penicilliger* (Ber.) (Acari: Mesostigmata). Bolletino di Zoologia, **38**: 1–33.

Fink, T.J. 1980. A comparison of mayfly (Ephemeroptera) instar determination methods. *In* Proceedings of the 3rd International Conference on Ephemeroptera: Advances in Ephemeroptera Biology, Winnipeg, Manitoba, 4–10 July 1979. *Edited by* J.F. Flannagan and K.E. Marshall. Plenum Press, New York. pp. 367–380.

Fitzgerald, T.D. 1993. Sociality in caterpillars. *In* Caterpillars: ecological and evolutionary constraints on foraging. *Edited by* N.E. Stamp and T.M. Casey. Chapman and Hall, London. pp. 372–404.

Force, D.C., and Messenger, P.S. 1964. Duration of development, generation time, and longevity of three hymenopterous parasites of *Therioaphis maculata* reared at various constant temperatures. Annals of the Entomological Society of America, **57**: 405–413.

Fouly, A.H., Abou-Setta, M.M., and Childers, C.C. 1995. Effects of diet on the biology and life tables of *Typhlodromalus peregrinus* (Acari: Phytoseiidae). Environmental Entomology, **24**: 870–874.

Fox, P.M., Pass, B.C., and Thurston, R. 1967. Laboratory studies on the rearing of *Aphidius smithi* (Hymenoptera: Braconidae) and its parasitism of *Acyrthosiphon pisum* (Homoptera: Aphididae). Annals of the Entomological Society of America, **60**: 1083–1087.

Francis, F., Haubruge, E., Hastir, P., and Gaspar, C. 2001. Effect of aphid host plant on development and reproduction of the third trophic level, the predator *Adalia bipunctata* (Coleoptera: Coccinellidae). Environmental Entomology, **30**: 947–952.

Frazer, B.D. 1972. Life tables and intrinsic rates of increase of apterous black bean aphids and pea aphids, on broad bean (Homoptera: Aphididae). The Canadian Entomologist, **104**: 1717–1722.

Frazer, B.D., and Gill, B. 1981. Age, fecundity, weight, and the intrinsic rate of increase of the lupine aphid *Macrosiphum albifrons* (Homoptera: Aphididae). The Canadian Entomologist, **113**: 739–745.

Furman, D.P. 1966. Biological studies on *Haemolaelaps centrocarpus* Berlese (Acarina: Laelapidae) with observations on its classification. Journal of Medical Entomology, **2**: 331–335.

Gaum, W.G., Giliomee, J.H., and Pringle, K.L. 1994. Life history and life tables of western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae), on English cucumbers. Bulletin of Entomological Research, **84**: 219–224.

Gerling, D., Conde, J.E., and Rabinovich, J.E. 1976. The comparative development of two egg parasites of *Rhodnius prolixus* (Hemiptera: Reduviidae), vector of Chagas' disease in Venezuela. The Canadian Entomologist, **108**: 427–432.

Gerling, D., Spivak, D., and Vinson, S.B. 1987. Life history and host discrimination of *Encarsia deserti* (Hymenoptera: Aphelinidae), a parasitoid of *Bemisia tabaci* (Homoptera: Aleyrodidae). Annals of the Entomological Society of America, **80**: 224–229.

Gerson, U., Capua, S., and Thorens, D. 1983. Life history and life tables of *Rhizoglyphus robini* Claparède (Acari: Astigmata: Acaridae). Acarologia, **24**: 439–448.

Giles, K.L., Stockland, R., Madden, R.D., Payton, M.E., and Dillwith, J.W. 2001. Preimaginal survival and development of *Coleomegilla maculata* and *Hippodamia convergens* (Coleoptera: Coccinellidae) reared on *Acyrthosiphon pisum*: effects of host plants. Environmental Entomology, **30**: 964–971.

Gillespie, D.R., Opit, G., and Roitberg, B. 2000. Effects of temperature and relative humidity on development, reproduction, and predation in *Feltiella acarisuga* (Vallot) (Diptera: Cecidomyiidae). Biological Control, **17**: 132–138.

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Girma, M., Wilde, G., and Reese, J.C. 1990. Influence of temperature and plant growth stage on development, reproduction, life span, and intrinsic rate of increase of the Russian wheat aphid (Homoptera: Aphididae). Environmental Entomology, **19**: 1438–1442.

Giron, A.R. 1978. Notes on the biology and diapause inducement of the hyperparasite *Gelis tenellus*. Annals of the Entomological Society of America, **71**: 827–829.

Gitonga, L.M., Lohr, B., Overholt, W.A., Magambo, J.K., and Mueke, J.M. 2002. Effect of temperature on the development of *Orius albidipennis* Reuter, a predator of the African legume flower thrips, *Megalurothrips sjostedti* Trybom. Insect Science and its Application, **22**: 215–220.

Gotoh, T. 1983. Life-history parameters of three species of *Schizotetranychus* on deciduous trees (Acarina: Tetranychidae). Applied Entomology and Zoology, **18**: 122–128.

Gotoh, T. 1986. Life-history parameters of the hawthorn spider mite, *Tetranychus viennensis* Zacher (Acarina: Tetranychidae), on deciduous oak. Applied Entomology and Zoology, **21**: 389–393.

Gotoh, T. 1987*a*. Life-history parameters of two species of the genus *Eotetranychus* (Acarina: Tetranychidae) on deciduous trees. Applied Entomology and Zoology, **22**: 45–51.

Gotoh, T. 1987*b*. Life-history parameters of *Panonychus ulmi* (Koch) (Acarina: Tetranychidae) on dwarf bamboo. Applied Entomology and Zoology, **22**: 112–114.

Gotoh, T. 1987*c*. Comparison of life-history parameters of two forms of *Panonychus akitanus* Ehara (Acarina: Tetranychidae). Applied Entomology and Zoology, **22**: 119–124.

Gotoh, T., and Gomi, K. 2003. Life-history traits of the Kanzawa spider mite *Tetranychus kanzawai* (Acari: Tetranychidae). Applied Entomology and Zoology, **38**: 7–14.

Gotoh, T., and Nagata, T. 2001. Development and reproduction of *Oligonychus coffeae* (Acari: Tetranychidae) on tea. International Journal of Acarology, **27**: 293–298.

Graf, B., Baumgärtner, J., and Delucchi, V. 1985. Life table statistics of three apple aphids, *Dysaphis plantaginea, Rhopalosiphum insertum*, and *Aphis pomi* (Homoptera, Aphididae), at constant temperatures. Zeitschrift für Angewandte Entomologie, **99**: 285–294.

Grant, J.F., and Shepard, M. 1984. Laboratory biology of *Meteorus autographae* (Hymenoptera: Braconidae), an indigenous parasitoid of soybean looper (Lepidoptera: Noctuidae) larvae. Environmental Entomology, **13**: 838–842.

Gray, L.J. 1981. Species composition and life histories of aquatic insects in a lowland Sonoran desert stream. American Midland Naturalist, **106**: 229–242.

Greenberg, B., and Tantawi, T.I. 1993. Different developmental strategies in two boreal blow flies (Diptera: Calliphoridae). Journal of Medical Entomology, **30**: 481–484.

Greenberg, S.M., Legaspi, B.C., Jr, Jones, W.A., and Enkegaard, A. 2000. Temperature-dependent life history of *Eretmocerus eremicus* (Hymenoptera: Aphelinidae) on two whitefly hosts (Homoptera: Aleyrodidae). Environmental Entomology, **29**: 851–860.

Grissa-Lebdi, K., Van Impe, G., and Lebrun, P. 2002. Demographic traits of *Eotetranychus pruni* from Belgian and Tunisian orchards, in comparison with *Tetranychus urticae*. Experimental and Applied Acarology, **26**: 209–217.

Grüber, K., and Dixon, A.F.G. 1988. The effect of nutrient stress on development and reproduction in an aphid. Entomologia Experimentalis et Applicata, **47**: 23–30.

Gupta, S.K., Dhooria, M.S., and Sidhu, A.S. 1975. Effect of food and temperature on the development, longevity and fecundity of sugarcane red spider mite, *Oligonychus indicus* (Hirst). Acarologia, **16**: 436–440.

Gutierrez, A.P., Morgan, D.J., and Havenstein, D.E. 1971. The ecology of *Aphis craccivora* Koch and subterranean clover stunt virus. I. The phenology of aphid populations and the epidemiology of the virus in pastures in south-east Australia. Journal of Applied Ecology, **8**: 699–721.

Hafez, S.M., Rasmy, A.H., and Elsawy, S.A. 1983. Effect of prey species and stages on predatory efficiency and development of the stigmaeid mite, *Agistemus exsertus*. Acarologia, **24**: 281–283.

Haines, C.P. 1981. Laboratory studies on the role of an egg predator, *Blattisocius tarsalis* (Berlese) (Acari: Ascidae), in relation to the natural control of *Ephestia cautella* (Walker) (Lepidoptera: Pyralidae) in warehouses. Bulletin of Entomological Research, **71**: 555–574.

Hambleton, E.J. 1938. A ocorrencia do acaro tropical "Tarsonemus latus Banks" (Acar., Tarsonemidae) causador da rasgadura das folhas nos algodoais de S. Paulo. Arquivos do Instituto Biologico, Sao Paulo, **9**: 201–209.

Hansen, L.S. 2000. Development time and activity threshold of *Trichogramma turkestanica* on *Ephestia kuehniella* in relation to temperature. Entomologia Experimentalis et Applicata, **96**: 185–188.

Harris, K.M., and Schreiner, I.H. 1992. A new species of gall midge (Diptera: Cecidomyiidae) attacking mango foliage in Guam, with observations on its pest status and biology. Bulletin of Entomological Research, **82**: 41–48.

Harrison, J.O. 1965. Studies on the biology of *Elachertus ceramidiae* (Hymenoptera: Eulophidae), a parasite of the banana pest *Ceramidia butleri* (Lepidoptera: Syntomidae). Annals of the Entomological Society of America, **58**: 64–66.

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Harrison, W.W., King, E.G., and Ouzts, J.D. 1985. Development of *Trichogramma exiguum* and *T. pretiosum* at five temperature regimes. Environmental Entomology, **14**: 118–121.

Hauer, F.R., and Benke, A.C. 1991. Rapid growth of snag-dwelling chironomids in a blackwater river: the influence of temperature and discharge. Journal of the North American Benthological Society, **10**: 154–164.

Hayakawa, D.L., Grafius, E., and Stehr, F.W. 1990. Effects of temperature on longevity, reproduction, and development of the asparagus aphid (Homoptera: Aphididae) and the parasitoid, *Diaeretiella rapae* (Hymenoptera: Braconidae). Environmental Entomology, **19**: 890–897.

Hazan, A., Gerson, U., and Tahori, A.S 1974. Life history and life table of the carmine spider mite. Acarologia, **15**: 414–440.

Hegazi, E.M., El-Gayar, F.H., Rawash, I.A., and Ali, S.A. 1978. Factors affecting the bionomics of *Piophila casei* (L.). Zeitschrift für Angewandte Entomologie, **85**: 327–335.

Herbert, H.J. 1961. Influence of various numbers of prey on rate of development, oviposition, and longevity of *Typhlodromus pyri* Scheuten (Acarina: Phytoseiidae) in the laboratory. The Canadian Entomologist, **93**: 380–384.

Herbert, H.J. 1981*a*. Biology, life tables, and intrinsic rate of increase of the European red mite, *Panonychus ulmi* (Acarina: Tetranychidae). The Canadian Entomologist, **113**: 65–71.

Herbert, H.J. 1981*b*. Biology, life tables, and innate capacity for increase of the twospotted spider mite, *Tetranychus urticae* (Acarina: Tetranychidae). The Canadian Entomologist, **113**: 371–378.

Hintze-Podufal, C., and Thorns, H.J. 1979. Development of poplar aphids (*Chaitophorus leucomelas*) on leaf discs at 15 °C and 25 °C. Zeitschrift für Angewandte Entomologie, **87**: 388–392.

Hirano, K., Honda, K., and Miyai, S. 1996. Effects of temperature on development, longevity and reproduction of the soybean aphid, *Aphis glycines* (Homoptera: Aphididae). Applied Entomology and Zoology, **31**: 178–180.

Ho, C.-C. 1989. Studies on the biology of *Macrocheles muscaedomesticae* (Scopoli) (Acarina: Macrochelidae). Chinese Journal of Entomology, Special Publication, **3**: 181–187.

Ho, C.-C., and Chen, W.-H. 1998. Life history, food consumption, and seasonal occurrence of *Feltiella minuta* (Diptera: Cecidomyiidae) on eggplant. Zhonghua Kunchong, **18**: 27–37. [In Chinese.]

Hodjat, S.H., and Bishop, G.W. 1978. Effects of crowding on clonal cultures of *Myzus persicae* (Sulz.). Entomologia Experimentalis et Applicata, **24**: 178–184.

Hokyo, N., Kiritani, K., Nakasuji, F., and Shiga, M. 1966. Comparative biology of the two scelionid egg parasites of *Nezara viridula* L. (Hemiptera: Pentatomidae). Applied Entomology and Zoology, **1**: 94–102.

Honda, J.Y., Nakashima, Y., and Hirose, Y. 1998. Development, reproduction and longevity of *Orius minutus* and *Orius sauteri* (Heteroptera: Anthocoridae) when reared on *Ephestia kuehniella* eggs. Applied Entomology and Zoology, **33**: 449–453.

Honěk, A., and Kocourek, F. 1990. Temperature and development time in insects: a general relationship between thermal constants. Zoologische Jahrbucher, Abteilung für Systematik, Okologie und Geographie der Tiere, **117**: 401–439.

Huber, J.T., Coté, S., and Boivin, G. 1997. Description of three new *Anaphes* species (Hymenoptera: Mymaridae), egg parasitoids of the carrot weevil, *Listronotus oregonensis* (LeConte) (Coleoptera: Curculionidae), and redescription of *Anaphes sordidatus* Girault. The Canadian Entomologist, **129**: 959–977.

Hughes, D., and Bryce, M.A. 1984. Biological characterization of two biotypes of pea aphid, one susceptible and the other resistant to fungal pathogens, coexisting on lucerne in Australia. Entomologia Experimentalis et Applicata, **36**: 225–229.

Hughes, R.D., Greenham, P.M., Tyndale-Biscoe, M., and Walker, J.M. 1972. A synopsis of observations on the biology of the Australian bushfly (*Musca vetustissima* Walker). Journal of the Australian Entomological Society, **11**: 311–331.

Hulshof, J., Ketoja, E., and Vänninen, I. 2003. Life history characteristics of *Frankliniella occidentalis* on cucumber leaves with and without supplemental food. Entomologia Experimentalis et Applicata, **108**: 19–32.

Hussein, M.Y., Yahya, H.J., and Schilthuzen, M. 1996. A new egg parasitoid for possible biological control of the asiatic maize borer in Malaysia. Pertanika Journal of Tropical Agricultural Science, **19**: 111–116.

Hussey, N.W., and Gurney, B. 1967. Bionomics and control of *Tarsonemus myceliophagus* (Acarina: Tarsonemidae) in mushroom composts. Entomologia Experimentalis et Applicata, **10**: 287–294.

Hutchison, W.D., and Hogg, D.B. 1984. Demographic statistics for the pea aphid (Homoptera: Aphididae) in Wisconsin and a comparison with other populations. Environmental Entomology, **13**: 1173–1181.

Hutchison, W.D., Butler, G.D., Jr., and Martin, J.M. 1986. Temperature-dependent development, mortality, and longevity of *Microplitis rufiventris* (Hymenoptera: Braconidae), a parasitoid of the beet armyworm (Lepidoptera: Noctuidae). Annals of the Entomological Society of America, **79**: 262–265.

Hutchison, W.D., Moratorio, M., and Martin, J.M. 1990. Morphology and biology of *Trichogrammatoidea bactrae* (Hymenoptera: Trichogrammatidae), imported from Australia as a parasitoid of pink bollworm (Lepidoptera: Gelechiidae)

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

eggs. Annals of the Entomological Society of America, **83**: 46–54.

Icuma, I.M., and Hirose, Y. 1996. Effects of temperature on development and survival of the egg parasitoid *Telenomus triptus* Nixon (Hymenoptera: Scelionidae) in two pentatomid hosts. Applied Entomology and Zoology, **31**: 168–170.

Isenhour, D.J. 1986. Developmental time, adult reproductive capability, and longevity of *Campoletis sonorensis* (Hymenoptera: Ichneumonidae) as a parasitoid of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Annals of the Entomological Society of America, **79**: 893–897.

Isenhour, D.J., and Yeargan, K.V. 1981. Effect of temperature on the development of *Orius insidiosus*, with notes on laboratory rearing. Annals of the Entomological Society of America, **74**: 114–116.

Jackson, C.G., and Butler, G.D., Jr. 1984. Development time of three species of *Bracon* (Hymenoptera: Braconidae) on the pink bollworm (Lepidoptera: Gelechiidae) in relation to temperature. Annals of the Entomological Society of America, **77**: 539–542.

Jackson, P.R., Hunter, P.E., and Payne, J.A. 1983. Biology of the pecan leaf scorch mite (Acari: Tetranychidae). Environmental Entomology, **12**: 55–59.

Jalil, M. 1972. A note on the life cycle of *Platynothrus peltifer.* Journal of the Kansas Entomological Society, **45**: 309–311.

James, D.G. 1986. Effect of temperature upon energy reserves of the monarch butterfly, *Danaus plexippus* L. (Lepidoptera: Danaidae). Australian Journal of Zoology, **34**: 373–379.

James, D.G., and Warren, G.N. 1991. Effect of temperature on development, survival, longevity and fecundity of *Trissolcus oenone* Dodd (Hymenoptera: Scelionidae). Journal of the Australian Entomological Society, **30**: 303–306.

Jansson, R.K., and Smilowitz, Z. 1985. Development and reproduction of the green peach aphid, *Myzus persicae* (Homoptera: Aphididae), on upper and lower leaves of three potato cultivars. The Canadian Entomologist, **117**: 247–252.

Jarjees, E.A., and Merritt, D.J. 2002. Development of *Trichogramma australicum* Girault (Hymenoptera: Trichogrammatidae) in *Helicoverpa* (Lepidoptera: Noctuidae) host eggs. Australian Journal of Entomology, **41**: 310–315.

Jeppson, L.R., Keifer, H.H., and Baker, E.W. 1975. Mites injurious to economic plants. University of California Press, Berkeley, California.

Johnson, S.J., and Smith, J.W., Jr. 1980. Biology of *Orgilus elasmopalpi* [Hym.: Braconidae] with *Elasmopalpus lignosellus* [Lep.: Pyralidae] as host. Annals of the Entomological Society of America, **73**: 572–575.

Jonsson, B., and Sandlund, O.T. 1975. Notes on winter activity of two *Diamesa* species (Diptera: Chironomidae) from Voos, Norway. Norwegian Journal of Entomology, **22**: 1–6.

Jowyk, E.A., and Smilowitz, Z. 1978. A comparison of growth and developmental rates of the parasite *Hyposoter exiguae* reared from two instars of its host, *Trichoplusia ni*. Annals of the Entomological Society of America, **71**: 467–472.

Kaakeh, W., and Dutcher, J.D. 1992. Estimation of life parameters of *Monelliopsis pecanis*, *Monellia caryella*, and *Melanocallis caryaefoliae* (Homoptera: Aphididae) on single pecan leaflets. Environmental Entomology, **21**: 632–639.

Kairo, M.T.K., and Murphy, S.T. 1999. Temperature and plant nutrient effects on the development, survival and reproduction of *Cinara* sp. nov., an invasive pest of cypress trees in Africa. Entomologia Experimentalis et Applicata, **92**: 147–156.

Kamata, N., and Igarashi, M. 1995. Relationship between temperature, number of instars, larval growth, body size, and adult fecundity of *Quadricalcarifera punctatella* (Lepidoptera: Notodontidae): cost–benefit relationship. Environmental Entomology, **24**: 648–656.

Kasuga, S., and Amano, H. 2000. Influence of temperature on the life history parameters of *Tyrophagus similis* Volgin (Acari: Acaridae). Applied Entomology and Zoology, **35**: 237–244.

Kawaguchi, M., and Tanaka, T. 1999. Biological characteristics of a larval endoparasitoid, *Cotesia plutellae* (Hymenoptera: Braconidae): host stage preference, subsequent sex ratio of progeny and mate location of males. Applied Entomology and Zoology, **34**: 213–221.

Kerns, D.L., Puterka, G.J., and Peters, D.C. 1989. Intrinsic rate of increase for greenbug (Homoptera: Aphididae) biotypes E, F, G, and H on small grain and sorghum varieties. Environmental Entomology, **18**: 1074–1078.

Kersting, U., Satar, S., and Uygun, N. 1999. Effect of temperature on development rate and fecundity of apterous *Aphis gossypii* Glover (Hom., Aphididae) reared on *Gossypium hirsutum* L. Journal of Applied Entomology, **123**: 23–27.

Kfir, R., and Luck, R.F. 1984. Effects of temperature and relative humidity on developmental rate and adult life span of three *Aphytis* species (Hym., Aphelinidae) parasitising California red scale. Zeitschrift für Angewandte Entomologie, **97**: 314–320.

Kieckhefer, R.W., Elliott, N.C., and Walgenbach, D.D. 1989. Effects of constant and fluctuating temperatures on developmental rates and demographic statistics of the English grain aphid (Homoptera: Aphididae). Annals of the Entomological Society of America, **82**: 701–706.

Kim, T.H., and Eckenrode, C.J. 1987. Bionomics of the bean seed maggot *Delia florilega* (Diptera: Anthomyiidae) under controlled conditions. Environmental Entomology, **16**: 881–886.

© 2006 Entomological Society of Canada

https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Kinn, D.N. 1984. Life cycle of *Dendrolaelaps neodisetus* (Mesostigmata: Digamasellidae), a nematophagous mite associated with pine bark beetles (Coleoptera: Scolytidae). Environmental Entomology, **13**: 1141–1144.

Kinn, D.N., and Witcosky, J.J. 1977. The life cycle and behaviour of *Macrocheles boudreauxi* Krantz. Zeitschrift für Angewandte Entomologie, **84**: 136–144.

Kirkland, R.L., Peries, I.D., and Hamilton, G.C. 1981. Differentiation and developmental rate of nymphal instars of greenbug reared on sorghum. Journal of the Kansas Entomological Society, **54**: 743–747.

Kivan, M., and Kilic, N. 2002. Host preference: parasitism, emergence and development of *Trissolcus semistriatus* (Hym., Scelionidae) in various host eggs. Journal of Applied Entomology, **126**: 395–399.

Klok, C.J., and Chown, S.L. 1999. Assessing the benefits of aggregation: thermal biology and water relations of anomalous Emperor Moth caterpillars. Functional Ecology, **13**: 417–427.

Knisley, C.B., and Swift, F.C. 1971. Biological studies of *Amblyseius umbraticus* (Acarina: Phytoseiidae). Annals of the Entomological Society of America, **64**: 813–822.

Komazaki, S. 1982. Effects of constant temperatures on population growth of three aphid species, *Toxoptera citricidus* (Kirkaldy), *Aphis citricola* van der Goot and *Aphis gossypii* Glover (Homoptera: Aphididae) on citrus. Applied Entomology and Zoology, **17**: 75–81.

Kouamé, K.L., and Mackauer, M. 1992. Influence of starvation on development and reproduction in apterous virginoparae of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae). The Canadian Entomologist, **124**: 87–95.

Kramer, D.A., and Hain, F.P. 1989. Effect of constant- and variable-humidity and temperature regimes on the survival and developmental periods of *Oligonychus ununguis* (Acarina: Tetranychidae) and *Neoseiulus fallacis* (Acarina: Phytoseiidae). Environmental Entomology, **18**: 741–746.

Krips, O.E., Witul, A., Willems, P.E.L., and Dicke, M. 1998. Intrinsic rate of population increase of the spider mite *Tetranychus urticae* on the ornamental crop gerbera: intraspecific variation in host plant and herbivore. Entomologia Experimentalis et Applicata, **89**: 159–168.

Kropczynska, D., Van de Vrie, M., and Tomczyk, A. 1988. Bionomics of *Eotetranychus tiliarium* and its phytoseiid predators. Experimental and Applied Acarology, **5**: 65–81.

Krüger, K., and Mills, N.J. 1990. Observations on the biology of three parasitoids of the spruce bark beetle, *Ips typographus* (Col., Scolytidae): *Coeloides bostrychorum, Dendrosoter middendorffii* (Hym., Braconidae) and *Rhopalicus tutela* (Hym., Pteromalidae). Journal of Applied Entomology, **110**: 281–291.

Kunnalaca, S., and Mueller, A.J. 1979. A laboratory study of *Apanteles marginiventris*, a parasite of green cloverworm. Environmental Entomology, **8**: 365–368.

Kunz, S.E., Berry, I.L., and Foerster, K.W. 1977. The development of the immature forms of *Stomoxys calcitrans*. Annals of the Entomological Society of America, **70**: 169–178.

Kuo, M.-H., and Chiang, T.-Y. 1999. Population parameters of *Aphis nerii* and the effect of temperature on its development. Zhonghua Kunchong, **19**: 297–306. [In Chinese.]

Kuramochi, K. 1985. Studies on the reproductive biology of the horn fly, *Haematobia irritans* (L.) (Diptera: Muscidae). II. Effect of temperature on follicle development and blood meal volume of laboratory-reared flies. Applied Entomology and Zoology, **20**: 264–270.

Kureck, A., and Fontes, R.J. 1996. The life cycle and emergence of *Ephoron virgo*, a large potamal mayfly that has returned to the River Rhine. Archiv für Hydrobiologie Supplement, **113**: 319–323.

Lactin, D.J., Holliday, N.J., Johnson, D.L., and Craigen, R. 1995. Improved rate model of temperature-dependent development by arthropods. Environmental Entomology, **24**: 68–75.

Lagace, C.F. 1969. Observations on the biology of *Mesidia nigra*, a parasite of *Iziphya punctata*. Annals of the Entomological Society of America, **62**: 532–536.

Laing, D.R., and Caltagirone, L.E. 1969. Biology of *Habrobracon lineatellae* (Hymenoptera: Braconidae). The Canadian Entomologist, **101**: 135–142.

Laing, J.E. 1968. Life history and life table of *Phytoseiulus persimilis* Anthias-Henriot. Acarologia, **10**: 578–588.

Laing, J.E. 1969. Life history and life table of *Tetranychus urticae* Koch. Acarologia, **11**: 33–42.

Lamb, R.J. 1992. Developmental rate of *Acyrthosiphon pisum* (Homoptera: Aphididae) at low temperatures: implications for estimating rate parameters for insects. Environmental Entomology, **21**: 10–19.

Lamb, R.J., Gerber, G.H., and Atkinson, G.H. 1984. Comparison of developmental rate curves applied to egg hatching data of *Entomoscelis americana* Brown (Coleoptera: Chrysomelidae). Environmental Entomology, **13**: 868–872.

Landwehr, V.R., and Allen, W.W. 1982. Life history of *Oligonychus subnudus* and *O. milleri* (Acari: Tetranychidae) and influence of temperature on development, survival, and oviposition. Annals of the Entomological Society of America, **75**: 340–345.

Laudien, H. 1973. Changing reaction systems. *In* Temperature and life. *Edited by* H. Precht, J.

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Christopherson, H. Hensel, and J. Larcher Springer-Verlag, New York. pp. 355–399.

Lawrence, R.K., Houseweart, M.W., Jennings, D.T., Southard, S.G., and Halteman, W.A. 1985. Development rates of *Trichogramma minutum* (Hymenoptera: Trichogrammatidae) and implications for timing augmentative releases for suppression of egg populations of *Choristoneura fumiferana* (Lepidoptera: Tortricidae). The Canadian Entomologist, **117**: 556–563.

Lebrun, P. 1970. Ecologie et biologie de *Nothrus palustris* (C.L. Koch) 3ème note: cycle de vie. Acarologia, **12**: 193–207.

Lebrun, P. 1971. Ecologie et biocenotique de quelques peuplements d'arthropodes édaphiques. Memoires de l'Institut Royal des Sciences Naturelles de Belgique, **165**: 1–203.

Lee, J.-H., and Ahn, J.J. 2000. Temperature effects on development, fecundity, and life table parameters of *Amblyseius womersleyi* (Acari: Phytoseiidae). Environmental Entomology, **29**: 265–271.

Lee, M.S., and Davis, D.W. 1968. Life history and behavior of the predatory mite *Typhlodromus occidentalis* in Utah. Annals of the Entomological Society of America, **61**: 251–255.

Leibee, G.L. 1984. Influence of temperature on development and fecundity of *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) on celery. Environmental Entomology, **13**: 497–501.

Levot, G.W., Brown, K.R., and Shipp, E. 1979. Larval growth of some calliphorid and sarcophagid Diptera. Bulletin of Entomological Research, **69**: 469–475.

Lim, G.T. 1986. Biological studies on *Trichogrammatoidea bactrae fumata* Nagaraja in the laboratory. Journal of Applied Entomology, **101**: 48–54.

Lindquist, E.E. 1983. Some thoughts on the potential for use of mites in biological control, including a modified concept of "parasitoids". *In* Biological control of pests by mites. *Edited by* M.A. Hoy, G.L. Cunningham, and L. Knutson. Special Publication 3304, Agricultural Experiment Station, Division of Agriculture and Natural Resources, University of California, Berkeley. pp. 12–20.

Lindquist, E.E. 1986. The world genera of Tarsonemidae (Acari: Heterostigmata): a morphological, phylogenetic and systematic revision, with a reclassification of family-group taxa in the Heterostigmata. Memoirs of the Entomological Society of Canada, **136**: 1–517.

Lindquist, E.E., and Bedard, W.D. 1961. Biology and taxonomy of mites of the genus *Tarsonemoides* (Acarina: Tarsonemidae) parasitizing eggs of bark beetles of the genus *Ips*. The Canadian Entomologist, **93**: 982–999.

Liu, S.-S. 1985. Aspects of the numerical and functional responses of the aphid parasite, *Aphidius sonchi*, in the laboratory. Entomologia Experimentalis et Applicata, **37**: 247–256.

Liu, S.-S., and Carver, M. 1985. Studies on the biology of *Aphidius sonchi* Marshall (Hymenoptera: Aphidiidae), a parasite of the sowthistle aphid, *Hyperomyzus lactucae* (L.) (Hemiptera: Aphididae). Bulletin of Entomological Research, **75**: 199–208.

Liu, S.-S., and Hughes, R.D. 1984*a*. The relationships between temperature and rate of development in two geographic stocks of *Aphidius sonchi* in the laboratory. Entomologia Experimentalis et Applicata, **36**: 231–238.

Liu, S.-S., and Hughes, R.D. 1984*b*. Effect of host age at parasitization by *Aphidius sonchi* on the development, survival, and reproduction of the sowthistle aphid, *Hyperomyus lactucae*. Entomologia Experimentalis et Applicata, **36**: 239–246.

Liu, S.-S., and Hughes, R.D. 1987. The influence of temperature and photoperiod on the development, survival and reproduction of the sowthistle aphid, *Hyperomyzus lactucae*. Entomologia Experimentalis et Applicata, **43**: 31–38.

Liu, S.-S., and Meng, X.-D. 1999. Modelling development time of *Myzus persicae* (Hemiptera: Aphididae) at constant and natural temperatures. Bulletin of Entomological Research, **89**: 55–63.

Liu, S.-S., and Meng, X.-D. 2000. Modelling development time of *Lipaphis erysimi* (Hemiptera: Aphididae) at constant and variable temperatures. Bulletin of Entomological Research, **90**: 337–347.

Liu, S.-S., Wang, X.-G., Shi, Z.-H., and Gebremeskel, F.B. 2001. The biology of *Diadromus collaris* (Hymenoptera: Ichneumonidae), a pupal parasitoid of *Plutella xylostella* (Lepidoptera: Plutellidae), and its interactions with *Oomyzus sokolowskii* (Hymenoptera: Eulophidae). Bulletin of Entomological Research, **91**: 461–469.

Liu, S.-S., Chen, F.-Z., and Zalucki, M.P. 2002. Development and survival of the diamondback moth (Lepidoptera: Plutellidae) at constant and alternating temperatures. Environmental Entomology, **31**: 221–231.

Liu, T.-X., and Stansly, P.A. 1996. Oviposition, development, and survivorship of *Encarsia pergandiella* (Hymenoptera: Aphelinidae) in four instars of *Bemisia argentifolii* (Homoptera: Aleyrodidae). Annals of the Entomological Society of America, **89**: 96–102.

Lo, K.-C., and Ho, C.-C. 1979. Ecological observations on rice tarsonemid mite, *Steneotarsonemus spinki* (Acarina: Tarsonemidae). Journal of Agricultural Research China, **28**: 181–192. [In Chinese, English summary.]

Lopes, R.B., and Alves, S.B. 2000. Criação e observações preliminares da biologia de *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) em Feijão-de-Porco *Canavalia ensiformis* (L.). Anais da Sociedade Entomologica do Brasil, **29**: 39–47.

Lowry, V.K., Smith, J.W., Jr, and Mitchell, F.L. 1992. Life-fertility tables for *Frankliniella fusca*

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

(Hinds) and *F. occidentalis* (Pergande) (Thysanoptera: Thripidae) on peanut. Annals of the Entomological Society of America, **85**: 744–754.

Lublinkhof, J., and Foster, D.E. 1977. Development and reproductive capacity of *Frankliniella occidentalis* (Thysanoptera: Thripidae) reared at three temperatures. Journal of the Kansas Entomological Society, **50**: 313–316.

Lykouressis, D.P. 1985. Temperature requirements of *Sitobion avenae* (F.) necessary for ecological studies, by assessing methods for the estimation of instar duration. Zeitschrift für Angewandte Entomologie, **100**: 479–493.

Lysyk, T.J. 1991. Use of life history parameters to improve a rearing method for horn fly, *Haematobia irritans irritans* (L.) (Diptera: Muscidae), on bovine hosts. The Canadian Entomologist, **123**: 1199–1207.

Lysyk, T.J. 1998*a*. Relationships between temperature and life-history parameters of *Stomoxys calcitrans* (Diptera: Muscidae). Journal of Medical Entomology, **35**: 107–119.

Lysyk, T.J. 1998*b*. Relationships between temperature and life history parameters of *Trichomalopsis sarcophagae* (Hymenoptera: Pteromalidae). Environmental Entomology, **27**: 488–498.

Lysyk, T.J. 2001*a*. Relationships between temperature and life history parameters of *Muscidifurax zaraptor* (Hymenoptera: Pteromalidae). Environmental Entomology, **30**: 147–156.

Lysyk, T.J. 2001*b*. Relationships between temperature and life history parameters of *Muscidifurax raptorellus* (Hymenoptera: Pteromalidae). Environmental Entomology, **30**: 982–992.

Lysyk, T.J., and Axtell, R.C. 1987. A simulation model of house fly (Diptera: Muscidae) development in poultry manure. The Canadian Entomologist, **119**: 427–437.

Mackauer, M. 1973. The population growth of the pea aphid biotype R1 on broad bean and pea (Homoptera: Aphididae). Zeitschrift für Angewandte Entomologie, **74**: 343–351.

Mackauer, M. 1983. Quantitative assessment of *Aphidius smithi* (Hymenoptera: Aphidiidae): fecundity, intrinsic rate of increase, and functional response. The Canadian Entomologist, **115**: 399–415.

Mackey, A.P. 1977. Growth and development of larval Chironomidae. Oikos, **28**: 270–275.

Madder, D.J., Surgeoner, G.A., and Helson, B.V. 1983. Number of generations, egg production, and developmental time of *Culex pipiens* and *Culex restuans* (Diptera: Culicidae) in southern Ontario. Journal of Medical Entomology, **20**: 275–287.

Mague, D.L., and Streu, H.T. 1980. Life history and seasonal population growth of *Oligonychus ilicis* infesting Japanese holly in New Jersey. Environmental Entomology, **9**: 420–424.

Mahmood, F. 1997. Life-table attributes of *Anopheles albimanus* (Wiedemann) under controlled laboratory conditions. Journal of Vector Ecology, **22**: 103–108.

Mallik, B., and ChannaBasavanna, G.P. 1983. Life history and life tables of *Tetranychus ludeni* and its predator *Amblyseius longispinosus* (Acari: Tetranychidae; Phytoseiidae). Indian Journal of Acarology, **8**: 1–12.

Marchenko, M.I., and Vinogradova, E.B. 1984. Influence of seasonal temperature changes on the rate of carcass destruction by fly larvae. Sudebno-Meditsinskaya Ekspertiza, **4**: 11–14. [In Russian.]

McCaffrey, J.P., and Horsburgh, R.L. 1986. Biology of *Orius insidiosus* (Heteroptera: Anthocoridae): a predator in Virginia apple orchards. Environmental Entomology, **15**: 984–988.

McCutcheon, G.S., and Harrison, W. 1987. Host range and development of *Microplitis rufiventris* (Hymenoptera: Braconidae), an imported parasitoid of several lepidopterous pests. Environmental Entomology, **16**: 855–858.

McLachlan, A. 1983. Life-history tactics of rain-pool dwellers. Journal of Animal Ecology, **52**: 545–561.

McLachlan, A.J., and Yonow, T. 1989. Reproductive strategies in rain-pool dwellers and the model freshwater insect. Hydrobiologia, **171**: 223–230.

McLeod, D.G.R., Whistlecraft, J.R., and Harris, C.R. 1985. An improved rearing procedure for the carrot rust fly (Diptera: Psilidae) with observations on life history and conditions controlling diapause induction and termination. The Canadian Entomologist, **117**: 1017–1024.

McMullen, R.D. 1967. The effects of photoperiod, temperature, and food supply on rate of development and diapause in *Coccinella novemnotata*. The Canadian Entomologist, **99**: 578–586.

McMurtry, J.A., and Scriven, G.T. 1964. Biology of the predaceous mite *Typhlodromus rickeri* (Acarina: Phytoseiidae). Annals of the Entomological Society of America, **57**: 362–367.

McMurtry, J.A., and Scriven, G.T. 1965. Life-history studies of *Amblyseius limonicus*, with comparative observations on *Amblyseius hibisci* (Acarina: Phytoseiidae). Annals of the Entomological Society of America, **58**: 106–111.

McNeil, J.N., and Rabb, R.L. 1973. Life histories and seasonal biology of four hyperparasites of the tobacco hornworm, *Manduca sexta* (Lepidoptera: Sphingidae). The Canadian Entomologist, **105**: 1041–1052.

Meier, P.G., and Torres, H.C. 1978. A modified method for rearing midges (Diptera: Chironomidae). Great Lakes Entomologist, **1**: 89–91.

Meyer, J.A., and Mullens, B.A. 1988. Development of immature *Fannia* spp. (Diptera: Muscidae) at constant laboratory temperatures. Journal of Medical Entomology, **25**: 165–171.

Meyerdirk, D.E., and Moratorio, M.S. 1987. Biology of *Anagrus giraulti* (Hymenoptera: Mymaridae), an egg parasioid of the beet leafhopper, *Circulifer*

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

*tenellus* (Homoptera: Cicadellidae). Annals of the Entomological Society of America, **80**: 272–277.

Michels, G.J., Jr, Lazar, M.D., Fritts, D.A., and Booker, J.D. 1997. Biotype E greenbug reproduction and development through three generations on resistant and susceptible winter wheat genotypes. Southwestern Entomologist, **22**: 431–437.

Micinski, S., Boethel, D.J., and Boudreaux, H.B. 1979. Influence of temperature and photoperiod on development and oviposition of the pecan leaf scorch mite, *Eotetranychus hicoriae*. Annals of the Entomological Society of America, **72**: 649–654.

Miller, J.C. 1992. Temperature-dependent development of the convergent lady beetle (Coleoptera: Coccinellidae). Environmental Entomology, **21**: 197–201.

Miller, G.W., and Isger, M.B. 1985. Effects of temperature on the development of *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae). Bulletin of Entomological Research, **75**: 321–328.

Miller, J.C., and Paustian, J.W. 1992. Temperature-dependent development of *Eriopis connexa* (Coleoptera: Coccinellidae). Environmental Entomology, **21**: 1139–1142.

Miller, K.V., and Williams, R.N. 1983. Biology and host preference of *Atheta coriari* (Coleoptera: Staphylinidae), an egg predator of Nitidulidae and Muscidae. Annals of the Entomological Society of America, **76**: 158–161.

Mishra, R.K. 1979. Bionomics of apholate resistant and normal strain of *Musca domestica* L. Zeitschrift für Angewandte Entomologie, **88**: 222–224.

Miura, K. 1990*a*. Effect of temperature on the development of *Gonatocerus cincticipitis* Sahad, an egg parasitoid of the green rice leafhopper. Applied Entomology and Zoology, **25**: 146–147.

Miura, K. 1990*b*. Life-history parameters of *Gonatocerus cincticipitis* Sahad (Hym., Mymaridae), an egg parasitoid of the green rice leafhopper, *Nephotettix cincticeps* Uhler (Hom., Cicadellidae). Journal of Applied Entomology, **110**: 353–357.

Miura, K. 1990*c*. Life-history parameters of *Paracentrobia andoi* (Ishii) (Hymenoptera, Trichogrammatidae), an egg parasitoid of the green rice leafhopper, *Nephotettix cincticeps* Uhler (Homoptera, Cicadellidae). Japanese Journal of Entomology, **58**: 585–591.

Miura, K., and Kobayashi, M. 1995. Reproductive properties of *Trichogramma chilonis* females on diamondback moth eggs. Applied Entomology and Zoology, **30**: 393–400.

Miyashita, K. 1997. Breeding and nymphal development of *Lycosa coelestis* L. Koch. Acta Arachnologia, **46**: 33–37.

Momen, F.M. 1995. Feeding, development and reproduction of *Amblyseius barkeri* (Acarina: Phytoseiidae) on various kinds of food substances. Acarologia, **36**: 101–105.

Momen, F.M., and El-Saway, S.A. 1993. Biology and feeding behaviour of the predatory mite, *Amblyseius swirskii* (Acari: Phytoseiidae). Acarologia, **34**: 199–204.

Morales-Ramos, J.A., and Cate, J.R. 1992*a*. Rate of increase and adult longevity of *Catolaccus grandis* (Burks) (Hymenoptera: Pteromalidae) in the laboratory at four temperatures. Environmental Entomology, **21**: 620–627.

Morales-Ramos, J.A., and Cate, J.R. 1992*b*. Laboratory determination of age-dependent fecundity, development and rate of increase of *Catolaccus grandis* (Burks) (Hymenoptera: Pteromalidae). Annals of the Entomological Society of America, **85**: 469–476.

Morales-Ramos, J.A., and Cate, J.R. 1993. Temperature-dependent developmental rates of *Catolaccus grandis* (Hymenoptera: Pteromalidae). Environmental Entomology, **22**: 226–233.

Morgan, D., Walters, K.F.A., and Aegerter, J.N. 2001. Effect of temperature and cultivar on pea aphid, *Acyrthosiphon pisum* (Hemiptera: Aphididae) life history. Bulletin of Entomological Research, **91**: 47–52.

Mottram, P., Kay, B.H., and Kettle, D.S. 1986. The effect of temperature on eggs and immature stages of *Culex annulirostris* Skuse (Diptera: Culicidae). Journal of the Australian Entomological Society, **25**: 131–135.

Mullen, M.A. 1981. Sweet potato weevil, *Cylas formicarius elegantulus* (Summers): development, fecundity, and longevity. Annals of the Entomological Society of America, **74**: 478–481.

Mullens, B.A., and Rutz, D.A. 1983. Development of immature *Culicoides variipennis* (Diptera: Ceratopogonidae) at constant laboratory temperatures. Annals of the Entomological Society of America, **76**: 747–751.

Murai, T. 2000. Effect of temperature on development and reproduction of the onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), on pollen and honey solution. Applied Entomology and Zoology, **35**: 499–504.

Murai, T. 2001*a*. Development and reproductive capacity of *Thrips hawaiiensis* (Thysanoptera: Thripidae) and its potential as a major pest. Bulletin of Entomological Research, **91**: 193–198.

Murai, T. 2001*b*. Life history study of *Thrips setosus*. Entomologia Experimentalis et Applicata, **100**: 245–251.

Mutch, R.A., and Pritchard, G. 1986. Development rates of eggs of some Canadian stoneflies (Plecoptera) in relation to temperature. Journal of the North American Benthological Society, **5**: 272–277.

Nagai, K., and Yano, E. 1999. Effects of temperature on the development and reproduction of *Orius sauteri* (Poppius) (Heteroptera: Anthocoridae), a predator of *Thrips palmi* Karny (Thysanoptera:

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Thripidae). Applied Entomology and Zoology, **34**: 223–229.

Nakai, Y., and Tsubaki, Y. 1986. Factors accelerating the development of German cockroach (*Blattella germanica* L.) nymphs reared in groups. Japanese Journal of Applied Entomology and Zoology, **30**: 1–6.

Nakata, T. 1995. Effect of rearing temperature on the development of *Orius sauteri* (Poppius) (Heteroptera: Anthocoridae). Applied Entomology and Zoology, **30**: 145–151.

Naranjo, S.E. 1993. Life history of *Trichogrammatoidea bactrae* (Hymenoptera: Trichogrammatidae), an egg parasitoid of pink bollworm (Lepidoptera: Gelechiidae), with emphasis on performance at high temperatures. Environmental Entomology, **22**: 1051–1059.

Naumann, I.D., and Sands, D.P.A. 1984. Two Australian *Elasmus* spp. (Hymenoptera: Elasmidae), parasitoids of *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae): their taxonomy and biology. Journal of the Australian Entomological Society, **23**: 25–32.

Nayar, J.K. 1968. Biology of *Culex nigripalpus* Theobald (Diptera: Culicidae). Part 1: Effects of rearing conditions on growth and the diurnal rhythm of pupation and emergence. Journal of Medical Entomology, **5**: 39–46.

Nebeker, A.V. 1973. Temperature requirements and life cycle of the midge *Tanytarsus dissimilis* (Diptera: Chironomidae). Journal of the Kansas Entomological Society, **46**: 160–165.

Neubauer, I., Raccah, B., Ishaaya, I., Aharonson, N., and Swirski, E. 1981. The effect of hosts exchange on the population dynamics of the spirea aphid *Aphis citricola* Van der Goot (Hom., Aphididae). Zeitschrift für Angewandte Entomologie, **91**: 231–236.

Neunzig, H.H. 1969. The biology of the tobacco budworm and the corn earworm in North Carolina: with particular reference to tobacco as a host. North Carolina Agricultural Experiment Station Technical Bulletin 196.

Nielsen, P.S. 2001. Developmental time of *Blattisocius tarsalis* (Acari: Ascidae) at different temperatures. Experimental and Applied Acarology, **25**: 605–608.

Nikam, P.K., and Pawar, C.V. 1993. Life tables and intrinsic rate of natural increase of *Bracon hebetor* Say (Hym., Braconidae) population on *Corcyra cephalonica* Staint. (Lep., Pyralidae), a key parasitoid of *Helicoverpa armigera* Hbn. (Lep., Noctuidae). Journal of Applied Entomology, **115**: 210–213.

Nikolakakis, N.N., Margaritopoulos, J.T., and Tsitsipis, J.A. 2003. Performance of *Myzus persicae* (Hemiptera: Aphididae) clones on different host-plants and their host preference. Bulletin of Entomological Research, **93**: 235–242.

Nikolei, E. 1961. Vergleichende Untersuchungen zur Fortpflanzung heterogener Gallmücken unter experimentellen Bedingungen. Zeitschrift für Morphologie und Ökologie der Tiere, **50**: 281–329.

Nishizuka, M., Azuma, A., and Masaki, S. 1998. Diapause response to photoperiod and temperature in *Lepisma saccharina* Linnaeus (Thysanura: Lepismatidae). Entomological Science, **1**: 7–14.

Noda, I. 1960. The emergence of winged viviparous female in aphid. VI. Difference in the rate of development between the winged and unwinged forms. Japan Journal of Ecology, **10**: 97–102.

Norton, R.A. 1994. Evolutionary aspects of oribatid mite life histories and consequences for the origin of the astigmata. *In* Mites: ecological and evolutionary analyses of life-history patterns. *Edited by* M.A. Houck. Chapman and Hall, New York, London. pp. 99–135.

Nowierski, R.M., Zeng, Z., and Scharen, A.L. 1995. Age-specific life table modeling of the Russian wheat aphid (Homoptera: Aphididae) on barley grown in benzimidazole agar. Environmental Entomology, **24**: 1284–1290.

Obrycki, J.J., and Tauber, M.J. 1978. Thermal requirements for development of *Coleomegilla maculata* (Coleoptera: Coccinellidae) and its parasite *Perilitus coccinellae* (Hymenoptera: Braconidae). The Canadian Entomologist, **110**: 407–412.

Obrycki, J.J., and Tauber, M.J. 1981. Phenology of three coccinellid species: thermal requirements for development. Annals of the Entomological Society of America, **74**: 31–36.

Obrycki, J.J., and Tauber, M.J. 1982. Thermal requirements for development of *Hippodamia convergens* (Coleoptera: Coccinellidae). Annals of the Entomological Society of America, **75**: 678–683.

Obrycki, J.J., Tauber, M.J., Tauber, C.A., and Gollands, B. 1985. *Edovum puttleri* (Hymenoptera: Eulophidae), an exotic egg parasitoid of the Colorado potato beetle (Coleoptera: Chrysomelidae): responses to temperate zone conditions and resistant potato plants. Environmental Entomology, **14**: 48–54.

OConnor, B.M. 1994. Life-history modifications in astigmatid mites. *In* Mites: ecological and evolutionary analyses of life-history patterns. *Edited by* M.A. Houck. Chapman and Hall, New York, London. pp. 136–159.

Oetting, R.D., and Yonke, T.R. 1971. Immature stages and biology of *Podisus placidus* and *Stiretrus fimbriatus* (Hemiptera: Pentatomidae). The Canadian Entomologist, **103**: 1505–1516.

Ohno, M. 1981. Ecological studies of chironomids on Tokyo, Japan. I. Estimation of the number of generations per year of *Chironomus yoshimatsui* (Diptera, Chironomidae) in the Zempukuji river. Japanese Journal of Ecology, **31**: 155–159. [In Japanese.]

Ohta, I. 2001. Effect of temperature on development of *Orius strigicollis* (Heteroptera: Anthocoridae)

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fed on *Frankliniella occidentalis* (Thysanoptera: Thripidae). Applied Entomology and Zoology, **36**: 483–488.

Ohta, I., and Ohtaishi, M. 2004. Fertility, longevity and intrinsic rate of increase of *Aphidius gifuensis* Ashmead (Hymenoptera: Braconidae) on the green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae). Applied Entomology and Zoology, **39**: 113–116.

Ohta, I., Miura, K., and Kobayashi, M. 2001. Life history parameters during immature stage of *Aphidius gifuensis* Ashmead (Hymenoptera: Braconidae) on green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae). Applied Entomology and Zoology, **36**: 103–109.

Oi, D.H., Sanderson, J.P., Youngman, R.R., and Barnes, M.M. 1989. Developmental times of the Pacific spider mite (Acari: Tetranychidae) on water-stressed almond trees. Environmental Entomology, **18**: 208–212.

Okabe, K. 1993. Developmental period and fecundity of *Histiogaster* sp. (Acari: Acaridae) on three fungi. Applied Entomology and Zoology, **28**: 479–487.

Okazawa, T., Horio, M., Suzuki, H., and Mogi, M. 1986. Colonization and laboratory bionomics of *Topomyia yanbarensis* (Diptera: Culicidae). Journal of Medical Entomology, **23**: 493–501.

Okazawa, T., Miyagi, I., Toma, T., Ramalingam, S., and Chang, M.S. 1991. Egg morphology and observations on the laboratory biology of *Armigeres* (*Leicesteria*) *digitatus* (Diptera: Culicidae) from Sarawak. Journal of Medical Entomology, **28**: 606–610.

Olaifa, J.I., and Akingbohungbe, A.E. 1982. Bionomics of *Bracon ?hancocki* (Wilkinson) (Hymenoptera: Braconidae), a larval parasite of *Cydia ptychora* (Meyrick) (Lepidoptera: Tortricidae) in Nigeria. Bulletin of Entomological Research, **72**: 567–572.

Olsen, A., Bale, J.S., Leadbeater, B.S.C., Callow, M.E., and Holden, J.B. 2003. Developmental thresholds and day-degree requirements of *Paratanytarsus grimmii* and *Corynoneura scutellata* (Diptera: Chironomidae): two midges associated with potable water treatment. Physiological Entomology, **28**: 315–322.

Orphanides, G.M., and Gonzalez, D. 1971. Fertility and life table studies with *Trichogramma pretiosum* and *T. retorridum* (Hymenoptera: Trichogrammatidae). Annals of the Entomological Society of America, **64**: 824–834.

Orr, D.B., Boethel, D.J., and Jones, W.A. 1985. Development and emergence of *Telenomus chloropus* and *Trissolcus basalis* (Hymenoptera: Scelionidae) at various temperatures and relative humidities. Annals of the Entomological Society of America, **78**: 615–619.

Osakabe, M., Kobayashi, S., and Ashihara, W. 1990. Development of the European red mite, *Panonychus ulmi* (Koch) (Acari: Tetranychidae), on mulberry and some other plants. Applied Entomology and Zoology, **25**: 326–328.

Økland, B. 1991. Laboratory studies of egg development and diapause in *Isoperla obscura* (Plecoptera) from a mountain stream in Norway. Freshwater Biology, **25**: 485–495.

Pak, G.A., and Oatman, E.R. 1982*a*. Biology of *Trichogramma brevicapillum*. Entomologia Experimentalis et Applicata, **32**: 61–67.

Pak, G.A., and Oatman, E.R. 1982*b*. Comparative life table, behavior and competition studies of *Trichogramma brevicapillum* and *T. pretiosum*. Entomologia Experimentalis et Applicata, **32**: 68–79.

Parkman, P., Dusky, J.A., and Waddill, V.H. 1989. Biological studies of *Liriomyza sativae* (Diptera: Agromyzidae) on castor bean. Environmental Entomology, **18**: 768–772.

Parr, H.C.M. 1962. Studies on *Stomoxys calcitrans* (L.) in Uganda, East Africa. II. Notes on life-history and behaviour. Bulletin of Entomological Research, **53**: 437–443.

Parrella, M.P., and Kok, L.T. 1977. The development and reproduction of *Bedellia somnulentella* on hedge bindweed and sweet potato. Annals of the Entomological Society of America, **70**: 925–928.

Patil, N.G., Baker, P.S., and Pollard, G.V. 1994. Life history parameters of the leucaena psyllid *Heteropsylla cubana* (Crawford) (Homoptera: Psyllidae) under various temperature and relative humidity regimes. Insect Science and its Application, **15**: 293–299.

Patro, B., and Behera, M.K. 2002. Biology and feeding potential of *Sphaerophoria javana* Wied. (Diptera: Syrphidae) on the bean aphid, *Aphis craccivora* Koch. Journal of Biological Control, **16**: 165–167.

Perng, J.J. 2002. Life history traits of *Aphis gossypii* Glover (Hom., Aphididae) reared on four widely distributed weeds. Journal of Applied Entomology, **126**: 97–100.

Perring, T.M., Holtzer, T.O., Toole, J.L., Norman, J.M., and Myers, G.L. 1984*a*. Influences of temperature and humidity on pre-adult development of the Banks grass mite (Acari: Tetranychidae). Environmental Entomology, **13**: 338–343.

Perring, T.M., Holtzer, T.O., Kalisch, J.A., and Norman, J.M. 1984*b*. Temperature and humidity effects on ovipositional rates, fecundity, and longevity of adult female Banks grass mites (Acari: Tetranychidae). Annals of the Entomological Society of America, **77**: 581–586.

Peters, D.C., Kerns, D., Puterka, G.J., and McNew, R. 1988. Feeding behavior, development, and damage by biotypes B, C, and E of *Schizaphis graminum* (Homoptera: Aphididae) on 'Wintermalt' and 'Post' barley. Environmental Entomology, **17**: 503–507.

Pettit, F.L., Loader, C.A., and Schon, M.K. 1994. Reduction of nitrogen concentration in the hydroponic solution on population growth rate of the

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aphids (Homoptera: Aphididae) *Aphis gossypii* on cucumber and *Myzus persicae* on pepper. Environmental Entomology, **23**: 930–936.

Phillipsen, W.J., and Coppel, H.C. 1977*a*. *Acotyledon formosani* sp. n. associated with the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Acarina: Acaridae — Isoptera: Rhinotermitidae). Journal of the Kansas Entomological Society, **50**: 399–409.

Phillipsen, W.J., and Coppel, H.C. 1977*b*. *Histiostoma formosana* sp.n. associated with the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Acarina: Anoetidae — Isoptera: Rhinotermitidae). Journal of the Kansas Entomological Society, **50**: 496–502.

Phoofolo, M.W., and Obrycki, J.J. 2000. Demographic analysis of reproduction in Nearctic and Palearctic populations of *Coccinella septempunctata* and *Propylea quatuordecimpunctata*. BioControl, **45**: 25–43.

Pillai, P.R.P., and Winston, P.W. 1969. Life history and biology of *Caloglyphus anomalus* Nesbitt (Acarina: Acaridae). Acarologia, **11**: 295–303.

Pimentel, D., Rumsey, M.W., and Streams, F.A. 1960. Rearing tyroglyphid mites on *Neurospora*. Annals of the Entomological Society of America, **53**: 549.

Plachter, H. 1983. Cave-dwelling flies in Central Europe: adaption to environment, especially to low temperatures (Diptera, Nematocera: Trichoceridae et Sciaridae). Oecologia, **58**: 367–372.

Plowright, R.C., and Pendrell, B.A. 1977. Larval growth in bumble bees (Hymenoptera: Apidae). The Canadian Entomologist, **109**: 967–973.

Porter, K. 1982. Basking behavior in larvae of the butterfly *Euphydryas aurinia*. Oikos, **38**: 308–312.

Powell, J.E., Shepard, M., and Sullivan, M.J. 1981. Use of heating degree day and physiological day equations for predicting development of the parasitoid *Trissolcus basalis*. Environmental Entomology, **10**: 1008–1011.

Prasad, V. 1967. Biology of the predatory mite *Phytoseiulus macropilis* in Hawaii (Acarina: Phytoseiidae). Annals of the Entomological Society of America, **60**: 905–908.

Prasad, N.G., Shakarad, M., Gohil, V.M., Sheeba, V., Rajamani, M., and Joshi, A. 2000. Evolution of reduced pre-adult viability and larval growth rate in laboratory populations of *Drosophila melanogaster* selected for shorter development time. Genetic Research, **76**: 249–259.

Pratissoli, D., and Parra, J.R.P. 2000. Fertility life table of *Trichogramma pretiosum* (Hym., Trichogrammatidae) in eggs of *Tuta absoluta* and *Phthorimaea operculella* (Lep., Gelechiidae) at different temperatures. Journal of Applied Entomology, **124**: 339–342.

Proctor, H.C., and Pritchard, G. 1990. Variability in the life history of *Unionicola crassipes*, a sponge-associated water mite (Acari: Unionicolidae). Canadian Journal of Zoology, **68**: 1227–1232.

Pruszynski, S., and Cone, W.W. 1973. Biological observations of *Typhlodromus occidentalis* (Acarina: Phytoseiidae) on hops. Annals of the Entomological Society of America, **66**: 47–51.

Putman, W.L. 1962. Life-history and behaviour of the predacious mite *Typhlodromus* (*T.*) *caudiglans* Schuster (Acarina: Phytoseiidae) in Ontario, with notes on the prey of related species. The Canadian Entomologist, **94**: 163–177.

Puttler, B., and Thewke, S.E. 1970. Biology of *Microplitis feltiae* (Hymenoptera: Braconidae), a parasite of the black cutworm, *Agrotis ipsilon*. Annals of the Entomological Society of America, **63**: 645–648.

Puttler, B., Gordh, G., and Long, S.H. 1980. Bionomics of *Euplectrus puttleri*, new species, an introduced parasite of the velvetbean caterpillar, *Anticarsia gemmatalis*, from South America. Annals of the Entomological Society of America, **73**: 28–35.

Qureshi, A.H., Oatman, E.R., and Fleschner, C.A. 1969. Biology of the spider mite, *Tetranychus evansi*. Annals of the Entomological Society of America, **62**: 898–903.

Rahim, A., Hashmi, A.A., and Khan, N.A. 1991. Effects of temperature and relative humidity on longevity and development of *Ooencyrtus papilionis* Ashmead (Hymenoptera: Eulophidae), a parasite of the sugarcane pest, *Pyrilla perpusilla* Walker (Homoptera: Cicadellidae). Environmental Entomology, **20**: 774–775.

Rahoo, G.M., and Luff, M.L. 1987. The biology of *Adelognathus granulatus* Perkins (Hym., Ichneumonidae) a parasitoid of the small gooseberry sawfly, *Pristiphora pallipes* (Lep.) (Hym., Tenthredinidae). Journal of Applied Entomology, **104**: 480–484.

Raney, H.G., Coles, L.W., Eikenbary, R.D., Morrison, R.D., and Starks, K.J. 1971. Host preference, longevity, developmental period and sex ratio of *Aphelinus asychis* with three sorghum-fed species of aphids held at controlled temperatures. Annals of the Entomological Society of America, **64**: 169–176.

Rasmy, A.H. 1978. Biology of the citrus brown mite, *Eutetranychus orientalis* as affected by some citrus species. Acarologia, **19**: 222–224.

Rawlins, J.E., and Lederhouse, R.C. 1981. Developmental influences of thermal behavior on monarch caterpillars (*Danaus plexippus*): an adaptation for migration (Lepidoptera: Nymphalidae: Danainae). Journal of the Kansas Entomological Society, **54**: 387–408.

Redborg, K.E., Hinesly, T.D., and Ziegler, E.L. 1983. Rearing *Psychoda alternata* (Diptera: Psychodidae) in the laboratory on digested sewage sludge, with some observations on its biology. Environmental Entomology, **12**: 412–415.

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Reis, P.R., and Alves, E.B. 1997. Biologia do ácaro predador *Euseius alatus* DeLeon (Acari: Phytoseiidae). Anais da Sociedade Entomologica do Brasil, **26**: 359–363.

Reisen, W.K., Siddiqui, T.F., Aslam, Y., and Malik, G.M. 1979. Geographic variation among the life table characteristics of *Culex tritaeniorhynchus* from Asia. Annals of the Entomological Society of America, **72**: 700–709.

Rice, R.E., and Strong, F.E. 1962. Bionomics of the tomato russet mite, *Vasates lycopersici* (Massee). Annals of the Entomological Society of America, **55**: 431–435.

Richardson, J.S. 1991. Seasonal food limitation of detritivores in a montane stream: an experimental test. Ecology, **72**: 873–887.

Ridgway, N.M., and Mahr, D.L. 1990. Reproduction, development, longevity, and host mortality of *Sympiesis marylandensis* (Hymenoptera: Eulophidae), a parasitoid of spotted tentiform leafminer (Lepidoptera: Gracillariidae), in the laboratory. Annals of the Entomological Society of America, **83**: 795–799.

Rivard, I. 1960. A technique for individual rearing of the predacious mite *Melichares dentriticus* (Berlese) (Acarina: Aceosejidae) with notes on its life history and behaviour. The Canadian Entomologist, **92**: 834–839.

Rivard, I. 1961. Influence of temperature and humidity on mortality and rate of development of immature stages of the mite *Tyrophagus putrescentiae* (Schrank) (Acarina: Acaridae) reared on mold cultures. Canadian Journal of Zoology, **39**: 419–426.

Rodriguez, J.G., and Stepien, Z.A. 1973. Biology and population dynamics of *Caloglyphus berlesei* (Michael) (Acarina: Acaridae) in xenic diet. Journal of the Kansas Entomological Society, **46**: 176–183.

Romeis, J., Shanower, T.G., and Madhuri, K. 2000. Biology and field performance of *Gryon clavigrallae* (Hymenoptera: Scelionidae), an egg parasitoid of *Clavigralla* spp. (Hemiptera: Coreidae) in India. Bulletin of Entomological Research, **90**: 253–263.

Rosillon, D. 1988. Food preference and relative influence of temperature and food quality on life history characteristics of a grazing mayfly, *Ephemerella ignita* (Poda). Canadian Journal of Zoology, **66**: 1474–1481.

Rout, G., and Senapati, B. 1968. Biology of the mustard aphid, *Lipaphis erysimi*, in India. Annals of the Entomological Society of America, **61**: 259–261.

Roy, M., Brodeur, J., and Cloutier, C. 2002. Relationship between temperature and developmental rate of *Stethorus punctillum* (Coleoptera: Coccinellidae) and its prey *Tetranychus mcdanieli* (Acarina: Tetranychidae). Environmental Entomology, **31**: 177–187.

Royer, T.A., Giles, K.L., Kindler, S.D., and Elliott, N.C. 2001. Developmental response of three geographic isolates of *Lysiphlebus testaceipes* (Hymenoptera: Aphididae) to temperature. Environmental Entomology, **30**: 637–641.

Ruberson, J.R., Tauber, M.J., and Tauber, C.A. 1988. Reproductive biology of two biotypes of *Edovum puttleri*, a parasitoid of Colorado potato beetle eggs. Entomologia Experimentalis et Applicata, **46**: 211–219.

Ruberson, J.R., Tauber, M.J., and Tauber, C.A. 1989. Intraspecific variability in hymenopteran parasitoids: comparative studies of two biotypes of the egg parasitoid *Edovum puttleri* (Hymenoptera: Eulophidae). Journal of the Kansas Entomological Society, **62**: 189–202.

Rudzińska, M. 1998. Life history of the phoretic predatory mite *Arctoseius semiscissus* (Acari: Ascidae) on a diet of sciarid fly eggs. Experimental and Applied Acarology, **22**: 643–648.

Ruf, A. 1996. Life-history patterns in soil-inhabiting mesostogmatid mites (Dermanyssina, Parasitina). *In* Acarology IX. Vol. I. Proceedings. *Edited by* R. Mitchell, D.J. Horn, G.R. Needham, and W.C. Welbourn. Ohio Biological Survey, Columbus, Ohio. pp. 621–628.

Sabelis, M.W. 1991. Life-history evolution of spider mites. *In* The Acari. Reproduction, development and life-history strategies. *Edited by* R. Schuster and P.W. Murphy. Chapman and Hall, London. pp. 23–49.

Saha, S., and Raychaudhuri, D. 1996. Temperature specific responses of *Aphis gossypii* Glover (Homoptera: Aphididae) on *Capsicum annuum* L. Research Bulletin of the Punjab University, Science, **46**: 107–137.

Sahad, A. 1982. Biology and morphology of *Gonatocerus* sp. (Hymenoptera, Mymaridae), an egg parasitoid of the green rice leafhopper, *Nephotettix cincticeps* Uhler (Homoptera, Deltocephalidae). I. Biology. Kontyû, **50**: 246–260.

Saitô, Y. 1979. Comparative studies on life histories of three species of spider mites (Acarina: Tetranychidae). Applied Entomology and Zoology, **14**: 83–94.

Saitô, Y., and Mori, H. 1981. Parameters related to potential rate of population increase of three predacious mites in Japan (Acarina: Phytoseiidae). Applied Entomology and Zoology, **16**: 45–47.

Saitô, Y., and Ueno, J. 1979. Life history studies on *Schizotetranychus celarius* (Banks) and *Aponychus corpuzae* Rimando as compared with other tetranychid mite species (Acarina: Tetranychidae). Applied Entomology and Zoology, **14**: 445–452.

Salto, C.E., Eikenbary, R.D., and Starks, K.J. 1983. Compatibility of *Lysiphlebus testaceipes* (Hymenoptera: Braconidae) with greenbug (Homoptera: Aphididae) biotypes "C" and "E" reared on susceptible and resistant oat varieties. Environmental Entomology, **12**: 603–604.

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Sánchez-Ramos, I., and Castañera, P. 2001. Development and survival of *Tyrophagus putrescentiae* (Acari: Acaridae) at constant temperatures. Environmental Entomology, **30**: 1082–1089.

Sanderson, J.P., and McMurtry, J.A. 1984. Life history studies of the predaceous mite *Phytoseius hawaiiensis*. Entomologia Experimentalis et Applicata, **35**: 227–234.

Sankarperumal, G., and Pandian, T.J. 1991. Effect of temperature and *Chlorella* density on growth and metamorphosis of *Chironomus circumdatus* (Kieffer) (Diptera). Aquatic Insects, **13**: 167–177.

Satar, S., and Yokomi, R. 2003. Effect of temperature and host on development of *Brachycaudus schwartzi* (Homoptera: Aphididae). Annals of the Entomological Society of America, **95**: 597–602.

Saunders, R.C., and Hsiao, T.H. 1970. Biology and laboratory propagation of *Amblymerus bruchophagi* (Hymenoptera: Pteromalidae), a parasite of the alfalfa seed chalcid. Annals of the Entomological Society of America, **63**: 744–749.

Scheiring, J.F., Davis, D.G., Ranasinghe, A., and Teare, C.A. 1984. Effects of larval crowding on life history parameters in *Drosophila melanogaster* Meigen (Diptera: Drosophilidae). Annals of the Entomological Society of America, **77**: 329–332.

Schlinger, E.I., and Hall, J.C. 1960. The biology, behavior, and morphology of *Praon palitans* Muesebeck, an internal parasite of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton) (Hymenoptera: Braconidae, Aphidiinae). Annals of the Entomological Society of America, **53**: 144–160.

Schlinger, E.I., and Hall, J.C. 1961. The biology, behavior, and morphology of *Trioxys* (*Trioxys*) *utilis*, an internal parasite of the spotted alfalfa aphid, *Therioaphis maculata* (Hymenoptera: Braconidae, Aphidiinae). Annals of the Entomological Society of America, **54**: 34–45.

Schmidt-Nielsen, K. 1984. Scaling: Why is animal size so important? Cambridge University Press, Cambridge.

Sciarappa, W.J., Jr., and Swift, F.C. 1977. Biological studies of *Typhlodromips sessor* (Acarina: Phytoseiidae). Annals of the Entomological Society of America, **70**: 285–288.

Scott, J.K., and Yeoh, P.B. 1999. Bionomics and the predicted distribution of the aphid *Brachycaudus rumexicolens* (Hemiptera: Aphididae). Bulletin of Entomological Research, **89**: 97–106.

Sengonca, C., and Liu, B. 1998. Biological studies on *Eretmocerus longipes* Compere (Hym., Aphelinidae), a parasitoid of *Aleurotuberculatus takahashi* David et Subramaniam (Hom., Aleyrodidae) in the laboratory. Journal of Applied Entomology, **122**: 207–211.

Sequeira, R., and Mackauer, M. 1992. Quantitative genetics of body size and development time in the parasitoid wasp *Aphidius ervi* (Hymenoptera: Aphidiidae). Canadian Journal of Zoology, **70**: 1102–1108.

Shahid, A.A., and Reisen, W.K. 1981. *Culex tritaeniorhynchus*: failure to detect heterosis in the life table characteristics of outcrossed laboratory colonies. Entomologia Experimentalis et Applicata, **30**: 58–62.

Shanower, T.G., Gutierrez, A.P., and Wightman, J.A. 1993. Effect of temperature on development rates, fecundity and longevity of the groundnut leaf miner, *Aproaerema modicella* (Lepidoptera: Gelechiidae), in India. Bulletin of Entomological Research, **83**: 413–419.

Shibao, M. 1996. Effects of temperature on development of the chillie thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), on grape. Applied Entomology and Zoology, **31**: 81–86.

Shih, C.-I.T., Poe, S.L., and Cromroy, H.L. 1976. Biology, life table, and intrinsic rate of increase of *Tetranychus urticae*. Annals of the Entomological Society of America, **69**: 362–364.

Shono, Y., and Hirano, M. 1993. Colonization and rearing of a wild strain of *Anopheles sinensis* Wiedemann (Diptera: Culicidae). Applied Entomology and Zoology, **28**: 571–573.

Siddig, M.A., and Elbadry, E.A. 1971. Biology of the spider mite *Eutetranychus sudanicus*. Annals of the Entomological Society of America, **64**: 806–809.

Siddiqui, W.H., Barlow, C.A., and Randolph, P.A. 1973. Effects of some constant and alternating temperatures on population growth of the pea aphid, *Acyrthosiphon pisum* (Homoptera: Aphididae). The Canadian Entomologist, **105**: 145–156.

Sigsgaard, L. 2000. The temperature-dependent duration of development and parasitism of three cereal aphid parasitoids, *Aphidius ervi*, *A. rhopalosiphi*, and *Praon volucre*. Entomologia Experimentalis et Applicata, **95**: 173–184.

Simon, J.C., Dedryver, C.A., Pierre, J.S., Tanguy, S., and Wegorek, P. 1991. The influence of clone and morph on the parameters of intrinsic rate of increase in the cereal aphids *Sitobion avenae* and *Rhopalosiphum padi*. Entomologia Experimentalis et Applicata, **58**: 211–220.

Smith, L. 1992. Effect of temperature on life history characteristics of *Anisopteromalus calandrae* (Hymenoptera: Pteromalidae) parasitizing maize weevil larvae in corn kernels. Environmental Entomology, **21**: 877–887.

Smith, L. 1993. Effect of humidity on life history characteristics of *Anisopteromalus calandrae* (Hymenoptera: Pteromalidae) parasitizing maize weevil (Coleoptera: Curculionidae) larvae in shelled corn. Environmental Entomology, **22**: 618–624.

Smith, J.C., and Newsom, L.D. 1970. The biology of *Amblyseius fallacis* (Acarina: Phytoseiidae) at various temperature and photoperiod regimes.

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

Annals of the Entomological Society of America, **63**: 460–462.

Smith, L., and Rutz, D.A. 1986. Development rate and survivorship of immature *Urolepis rufipes* (Hymenoptera: Pteromalidae), a parasitoid of pupal house flies. Environmental Entomology, **15**: 1301–1306.

Smith, R.F., and Hardman, J.M. 1986. Rates of feeding, oviposition, development, and survival of *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) on several weeds. The Canadian Entomologist, **118**: 753–759.

Smith, S.M., and Hubbes, M. 1986. Isoenzyme patterns and biology of *Trichogramma minutum* as influenced by rearing temperature and host. Entomologia Experimentalis et Applicata, **42**: 249–258.

Smith, J.W., Jr., Rodriguez-Del-Bosque, L.A., and Agnew, C.W. 1990. Biology of *Mallochia pyralidis* (Hymenoptera: Ichneumonidae), an ectoparasite of *Eoreuma loftini* (Lepidoptera: Pyralidae) from Mexico. Annals of the Entomological Society of America, **83**: 961–966.

Solbreck, C., Anderson, D.B., and Förare, J. 1990. Migration and coordination of life-cycles as exemplified by Lygaeine bugs. *In* Insect life cycles: genetics, evolution and co-ordination. *Edited by* F. Gilbert. Springer-Verlag, London. pp. 197–214.

Soliman, Z.R., Zaher, M.A., and Mohamed, M.I. 1978. Biology and predaceous efficiency of *Macrocheles matrius* (Hull) (Acari, Mesostigmata). Zeitschrift für Angewandte Entomologie, **85**: 225–230.

Stathas, G.J., Eliopoulos, P.A., Kontodimas, D.C., and Giannopapas, J. 2001. Parameters of reproductive activity in females of *Harmonia axyridis* (Coleoptera: Coccinellidae). European Journal of Entomology, **98**: 547–549.

Stavraki, H.G. 1976. Effects of diet and temperature on development, fecundity and longevity of a *Trichogramma* sp., parasite of olive moth. Zeitschrift für Angewandte Entomologie, **81**: 381–386.

Steiner, M.Y., Goodwin, S., Wellham, T.M., Barchia, I.M., and Spohr, L.J. 2003*a*. Biological studies of the Australian predatory mite *Typhlodromips montdorensis* (Schicha) (Acari: Phytoseiidae), a potential biocontrol agent for western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Australian Journal of Entomology, **42**: 124–130.

Steiner, M.Y., Goodwin, S., Wellham, T.M., Barchia, I.M., and Spohr, L.J. 2003*b*. Biological studies of the Australian predatory mite *Typhlodromalus lailae* (Schicha) (Acari: Phytoseiidae). Australian Journal of Entomology, **42**: 131–137.

Steinkraus, D.C., and Cross, E.A. 1993. Description and life history of *Acarophenax mahunkai*, n. sp. (Acari, Tarsonemina: Acarophenacidae), an egg parasite of the lesser mealworm (Coleoptera: Tenebrionidae). Annals of the Entomological Society of America, **86**: 239–249.

Strixino, S.T., and Strixino, G. 1982. Ciclo de vida de *Chironomus sancticaroli* (Diptera: Chironomidae). Revista Brasileira de Entomologia, **26**: 183–189.

Summers, C.G., Coviello, R.L., and Gutierrez, A.P. 1984. Influence of constant temperatures on the development and reproduction of *Acyrthosiphon kondoi* (Homoptera: Aphididae). Environmental Entomology, **13**: 236–242.

Sumner, L.C., Dorschner, K.W., Ryan, J.D., Eikenbary, R.D., Johnson, R.C., and McNew, R.W. 1986. Reproduction of *Schizaphis graminum* (Homoptera: Aphididae) on resistant and susceptible wheat genotypes during simulated drought stress induced with polyethylene glycol. Environmental Entomology, **15**: 756–762.

Sunose, T. 1985. Population regulation of the euonymus gall midge *Masakimyia pustulae* Yukawa and Sunose (Diptera: Cecidomyiidae) by hymenopterous parasitoids. Researches on Population Ecology, **27**: 287–300.

Syrjämäki, J. 1965. Laboratory studies on the swarming behaviour of *Chironomus strenzkei* Fittkau in litt. (Dipt., Chironomidae). Annales Zoologici Fennici, **2**: 145–152.

Takada, Y., Kawamura, S., and Tanaka, T. 2000. Biological characteristics: growth and development of the egg parasitoid *Trichogramma dendrolimi* (Hymenoptera: Trichogrammatidae) on the cabbage armyworm *Mamestra brassicae* (Lepidoptera: Noctuidae). Applied Entomology and Zoology, **35**: 369–379.

Takafuji, A., and Chant, D.A. 1976. Comparative studies of two species of predacious phytoseiid mites (Acarina: Phytoseiidae), with special reference to their responses to the density of their prey. Researches on Population Ecology, **17**: 255–310.

Takagi, M., and Murakami, K. 1997. Effect of temperature on development of *Paratelenomus saccharalis* (Hymenoptera: Scelionidae), an egg parasitoid of *Megacopta punctatissimum* (Hemiptera: Plataspidae). Applied Entomology and Zoology, **32**: 659–660.

Takahashi, F., and Chant, D.A. 1992. Adaptive strategies in the genus *Phytoseiulus* Evans (Acari: Phytoseiidae): I. Developmental times. International Journal of Acarology, **18**: 171–176.

Tamaki, G., Annis, B., Fox, L., Gupta, R.K., and Meszleny, A. 1982. Comparison of yellow holocyclic and green anholocyclic strains of *Myzus persicae* (Sulzer): low temperature adaptability. Environmental Entomology, **11**: 231–233.

Tamaki, G., Gefre, J.A., and Halfhill, J.E. 1983. Biology of morphs of *Brachycolus asparagi* Mordvilko (Homoptera: Aphididae). Environmental Entomology, **12**: 1120–1124.

Tan, F.M., and Ward, C.R. 1977. Laboratory studies on the biology of the Banks grass mite. Annals of

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https://doi.org/10.4039/n06-803 Published online by Cambridge University Press

the Entomological Society of America, **70**: 534–536.

Tang, Y.Q., Lapointe, S., Brown, L.G., and Hunter, W.B. 1999. Effects of host plant and temperature on the biology of *Toxoptera citricida* (Homoptera: Aphididae). Environmental Entomology, **28**: 895–900.

Tanigoshi, L.K., and Browne, R.W. 1978. Influence of temperature on life table parameters of *Metaseiulus occidentalis* and *Tetranychus mcdanieli* (Acarina: Phytoseiidae, Tetranychidae). Annals of the Entomological Society of America, **71**: 313–316.

Tanigoshi, L.K., Hoyt, S.C., Browne, R.W., and Logan, J.A. 1975*a*. Influence of temperature on population increase of *Tetranychus mcdanieli* (Acarina: Tetranychidae). Annals of the Entomological Society of America, **68**: 972–978.

Tanigoshi, L.K., Hoyt, S.C., Browne, R.W., and Logan, J.A. 1975*b*. Influence of temperature on population increase of *Metaseiulus occidentalis* (Acarina: Phytoseiidae). Annals of the Entomological Society of America, **68**: 979–986.

Tanigoshi, L.K., Fargerlund, J., and Nishio-Wong, J.Y. 1981. Significance of temperature and food resources to the developmental biology of *Amblyseius hibisci* (Chant) (Acarina, Phytoseiidae). Zeitschrift für Angewandte Entomologie, **92**: 409–419.

Tanigoshi, L.K., Nishio-Wong, J.Y., and Fargerlund, J. 1983. Greenhouse- and laboratory-rearing studies of *Euseius hibisci* (Chant) (Acarina: Phytoseiidae), a natural enemy of the citrus thrips, *Scirtothrips citri* (Moulton) (Thysanoptera: Thripidae). Environmental Entomology, **12**: 1298–1302.

Tatara, A. 1994. Effect of temperature and host plant on the development, fertility and longevity of *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae). Applied Entomology and Zoology, **29**: 31–37.

Teulon, D.A.J., and Penman, D.R. 1991. Effects of temperature and diet on oviposition rate and development time of the New Zealand flower thrips, *Thrips obscuratus*. Entomologia Experimentalis et Applicata, **60**: 143–155.

Thongtab, T., Chandrapatya, A., and Baker, G.T. 2001. Biology and efficacy of the predatory mite, *Amblyseius longispinosus* (Evans) (Acari, Phytoseiidae) as a biological control agent of *Eotetranychus cendanai* Rimando (Acari, Tetranychidae). Entomologia Experimentalis et Applicata, **125**: 543–549.

Timms, S., Ferro, D.N., and Emberson, R.M. 1981. General biology and nomenclature of *Sancassania berlesei* (Michael). Acarologia, **22**: 385–390.

Tiwari, N.K. 1974. *Eurytoma nesiotes* Crawford (Hym.: Chalcidoidea) an external parasite of gall midge *Asphondylia sesami* Felt. Zeitschrift für Angewandte Entomologie, **77**: 189–194.

Toyoshima, S., and Amano, H. 1999. Comparison of development and reproduction in offspring produced by females of *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae) under two prey conditions. Applied Entomology and Zoology, **34**: 285–292.

Tsai, J.H., and Wang, K. 1999. Life table study of brown citrus aphid (Homoptera: Aphididae) at different temperatures. Environmental Entomology, **28**: 412–419.

Tsai, J.H., Yue, B., Webb, S.E., Funderburk, J.E., and Hsu, H.T. 1995. Effects of host plant and temperature on growth and reproduction of *Thrips palmi* (Thysanoptera: Thripidae). Environmental Entomology, **24**: 1598–1603.

Tsitsipis, J.A., and Mittler, T.E. 1976. Development, growth, reproduction, and survival of apterous virginoparae of *Apis fabae* at different temperatures. Entomologia Experimentalis et Applicata, **19**: 1–10.

Tsueda, H., and Tsuchida, K. 1998. Differences in spatial distribution and life history parameters of two sympatric whiteflies, the greenhouse whitefly (*Trialeurodes vaporariorum* Westwood) and the silverleaf whitefly (*Bemisi argentifolii* Bellows & Perring), under greenhouse and laboratory conditions. Applied Entomology and Zoology, **33**: 379–383.

Tyler, B.M.J., and Jones, P.A. 1974. Influence of low temperature on development and successful emergence of *Lysiphlebus testaceipes*, a parasite of the greenbug. Environmental Entomology, **3**: 377–379.

Uematsu, H. 1981*a*. Bionomics of *Euplectrus kuwanae* Crawford (Hymenoptera: Eulophidae), a parasitoid of *Argyrogramma albostriata* (Bremer et Grey). Applied Entomology and Zoology, **16**: 57–59.

Uematsu, H. 1981*b*. The ovipositional behavior in *Euplectrus kuwanae* Crawford (Hymenoptera: Eulophidae), a parasitoid of *Argyrogramma albostriata* (Bremer et Grey) (Lepidoptera: Noctuidae). Applied Entomology and Zoology, **16**: 443–450.

Uichanco, L.B. 1924. Studies on the embryology and post-natal development of the Aphididae with special reference to the history of the 'symbiotic organ' or 'mycetom'. Phillipine Journal of Science, **24**: 143–247.

Ulrich, H., Petalas, A., and Camenzind, R. 1972. Der Generationswechsel von *Mycophila speyeri* Barnes, einer Gallmücke mit paedogenetischer Fortpflanzung. Revue Suisse de Zoologie, **79**(Suppl.): 75–83.

Umeh, E.D.N. 1988. Development, oviposition, host feeding and sex determination in *Epidinocarsis lopezi* (De Santis) (Hymenoptera: Encyrtidae). Bulletin of Entomological Research, **78**: 605–611.

Urbaneja, A., Llácer, E., Tomás, O., Jacas, J., and Garrido, A. 1999. Effect of temperature on development and survival of *Cirrospilus* sp. near *lyncus* (Hymenoptera: Eulophidae), parasitoid of the

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citrus leafminer (Lepidoptera: Gracillariidae). Environmental Entomology, **28**: 339–344.

Urbaneja, A., Llácer, E., Garrido, A., and Jacas, J. 2001. Effect of temperature on the life history of *Cirrospilus* sp. near *lyncus* (Hymenoptera: Eulophidae), a parasitoid of *Phyllocnistis citrella* (Lepidoptera: Gracillariidae). Biological Control, **21**: 293–299.

Urbaneja, A., Hinarejos, R., Llácer, E., Garrido, A., and Jacas, J. 2002. Effect of temperature on life history of *Cirrospilus vittatus* (Hymenoptera: Eulophidae), an ectoparasitoid of *Phyllocnistis citrella* (Lepidoptera: Gracillariidae). Journal of Economic Entomology, **95**: 250–255.

Utida, S. 1957. Developmental zero temperature in insects. Japanese Journal of Applied Entomology and Zoology, **1**: 46–53. [In Japanese.]

van Rijn, P.C.J., Mollema, C., and Steenhuis-Broers, G.M. 1995. Comparative life history studies of *Frankliniella occidentalis* and *Thrips tabaci* (Thysanoptera: Thripidae) on cucumber. Bulletin of Entomological Research, **85**: 285–297.

van Steenis, M.J. 1993. Intrinsic rate of increase of *Aphidius colemani* Vier. (Hym., Braconidae), a parasitoid of *Aphis gossypii* Glov. (Hom., Aphididae), at different temperatures. Journal of Applied Entomology, **116**: 192–198.

van Steenis, M.J. 1995. Evaluation of four aphidiine parasitoids for biological control of *Aphis gossypii*. Entomologia Experimentalis et Applicata, **75**: 151–157.

Vänninen, I. 2001. Biology of the shore fly *Scatella stagnalis* in rockwool under greenhouse conditions. Entomologia Experimentalis et Applicata, **98**: 317–328.

Vaught, G.L., and Stewart, K.W. 1974. The life history and ecology of the stonefly *Neoperla clymene* (Newman) (Plecoptera: Perlidae). Annals of the Entomological Society of America, **67**: 167–178.

Villanueva, B.J.R., and Strong, F.E. 1964. Laboratory studies on the biology of *Rhopalosiphum padi* (Homoptera: Aphidae). Annals of the Entomological Society of America, **57**: 609–613.

Vogt, W.G., Walker, J.M., and Runko, S. 1990. Estimation of development times for immature stages of the bush fly, *Musca vetustissima* Walker (Diptera: Muscidae), and their simulation from air temperature and solar radiation records. Bulletin of Entomological Research, **80**: 73–78.

Wade, C.F., and Rodriguez, J.G. 1961. Life history of *Macrocheles muscaedomesticae* (Acarina: Macrochelidae), a predator of the house fly. Annals of the Entomological Society of America, **54**: 776–781.

Walter, D.E., and Ikonen, E.K. 1989. Species, guilds, and functional groups: taxonomy and behavior in nematophagous arthropods. Journal of Nematology, **21**: 315–327.

Walter, D.E., and Proctor, H.C. 1999. Mites: ecology, evolution and behaviour. University of New South Wales Press, Sydney, Australia and CABI, Wallingford, United Kingdom.

Wang, J.-J., and Tsai, J.H. 2000. Effect of temperature on the biology of *Aphis spiraecola* (Homoptera: Aphididae). Annals of the Entomological Society of America, **93**: 874–883.

Wang, J.-J., and Tsai, J.H. 2001. Development, survival and reproduction of black citrus aphid, *Toxoptera aurantii* (Hemiptera: Aphididae), as a function of temperature. Bulletin of Entomological Research, **91**: 477–487.

Wang, K., Tsai, J.H., and Harrison, N.A. 1997. Influence of temperature on development, survivorship, and reproduction of buckthorn aphid (Homoptera: Aphididae). Annals of the Entomological Society of America, **90**: 62–68.

Wcislo, W.T. 1987. The roles of seasonality, host synchrony, and behavior in the evolutions and distributions of nest parasites in Hymenoptera (Insecta), with special reference to bees (Apoidea). Biological Reviews and Biological Proceedings of the Cambridge Philosophical Society, **62**: 515–543.

Wellings, P.W. 1981. The effect of temperature on the growth and reproduction of two closely related aphid species. Ecological Entomology, **6**: 209–214.

Wellings, P.W. 1985. Growth, development and survival of *Acyrthosiphon kondoi* (Homoptera: Aphididae) on five cultivars of lucerne. Journal of the Australian Entomological Society, **24**: 155–160.

Weseloh, R.M. 1984. Effect of size, stress, and ligation of gypsy moth (Lepidoptera: Lymantriidae) larvae on development of the tachinid parasite *Compsilura concinnata* Meigen (Diptera: Tachinidae). Annals of the Entomological Society of America, **77**: 423–428.

White, N.D., and Laing, J.E. 1977. Some aspects of the biology and a laboratory life table of the acarine predator *Zetzellia mali*. The Canadian Entomologist, **109**: 1275–1281.

White, N.D.G., and Sinha, R.N. 1981. Life history and population dynamics of the mycophagous mite *Tarsonemus granarius* Lindquist (Acarina: Tarsonemidae). Acarologia, **22**: 353–360.

Whitfield, G.H., and Richards, K.W. 1985. Influence of temperature on survival and rate of development of *Pteromalus venustus* (Hymenoptera: Pteromalidae), a parasite of the alfalfa leafcutter bee (Hymenoptera: Megachilidae). The Canadian Entomologist, **117**: 811–818.

Wohltmann, A. 2000. The evolution of life histories in Parasitengona (Acari: Prostigmata). Acarologia, **41**: 145–204.

Wood, D.M., Dang, P.T., and Ellis, R.A. 1979. The mosquitoes of Canada (Diptera: Culicidae). The insects and arachnids of Canada, Part 6. Agriculture Canada Publication 1686.

Woodring, J.P. 1969. Observations on the biology of six species of acarid mites. Annals of the Entomological Society of America, **62**: 102–108.

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Woodring, J.P., and Cook, E.F. 1962. The biology of *Ceratozetes cisalpinus* Berlese, *Scheloribates laevigatus* Koch, and *Oppia neerlandica* Oudemans (Oribatei), with a description of all stages. Acarologia, **4**: 101–137.

Wrensch, D.L., and Bruce, W.A. 1991. Sex-ratio, fitness and capacity for population increase in *Pyemotes tritici* (L.-F. & M.) (Pyemotidae). *In* The Acari. Reproduction, development and life-history strategies. *Edited by* R. Schuster and P.W. Murphy. Chapman and Hall, London. pp. 209–221.

Wright, L.C., and Cone, W.W. 1988. Population statistics for the asparagus aphid, *Brachycorynella asparagi* (Homoptera: Aphididae), on different ages of asparagus foliage. Environmental Entomology, **17**: 699–703.

Wyatt, I.J. 1963. Pupal paedogenesis in the Cecidomyiidae (Diptera) — II. Proceedings of the Royal Entomological Society of London A, **38**: 136–144.

Wyatt, I.J. 1964. Immature stages of Lestremiinae (Diptera: Cecidomyiidae) infesting cultivated mushrooms. Transactions of the Royal Entomological Society of London, **116**: 15–27.

Wyatt, I.J. 1967. Pupal paedogenesis in the Cecidomyiidae (Diptera) 3 – A reclassification of the Heteropezini. Transactions of the Royal Entomological Society of London, **119**: 71–98.

Xia, J.Y., van der Werf, W., and Rabbinge, R. 1999. Influence of temperature on bionomics of cotton aphid, *Aphis gossypii*, on cotton. Entomologia Experimentalis et Applicata, **90**: 25–35.

Yang, Y., and Joern, A. 1994. Compensatory feeding in response to variable food quality by *Melanoplus differentialis*. Physiological Entomology, **19**: 75–82.

Ydergaard, S., Enkegaard, A., and Brødsgaard, H.F. 1997. The predatory mite *Hypoaspis miles*: temperature dependent life table characteristics on a diet of sciarid larvae, *Bradysia paupera* and *B. tritici*. Entomologia Experimentalis et Applicata, **85**: 177–187.

Yeargan, K.V. 1980. Effects of temperature on developmental rate of *Telenomus podisi* (Hymenoptera: Scelionidae). Annals of the Entomological Society of America, **73**: 339–342.

Yeargan, K.V. 1982. Reproductive capability and longevity of the parasitic wasps *Telenomus podisi* and *Trissolcus euschisti*. Annals of the Entomological Society of America, **75**: 181–183.

Yeargan, K.V. 1983. Effects of temperature on developmental rate of *Trissolcus euschisti* (Hymenoptera: Scelionidae), a parasite of stink bug eggs. Annals of the Entomological Society of America, **76**: 757–760.

Yousef, A.A. 1981. Morphology and biology of *Typhlodromus africanus* n. sp. (Acarina: Mesostigmata: Phytoseiidae). Acarologia, **22**: 121–125.

Yousef, A.A., El-Badry, E.A., and Metwally, S.H. 1979. Life history of the anoetid mite *Histiosoma cataglyphi* Yousef et Metwally, with a description of the immature stages (Acari, Astigmata, Anoetoidea). Zeitschrift für Angewandte Entomologie, **87**: 225–229.

Yousef, A.A., Zaher, M.A., and Kandil, M.M. 1982*a*. Effect of prey and temperature on the development and biology of *Cheyletus malaccensis* Oudemans (Acari, Cheyletidae). Zeitschrift für Angewandte Entomologie, **93**: 39–42.

Yousef, A.A., Zaher, M.A., and Abd El-Hafiez, A.M. 1982*b*. Effect of prey on the biology of *Amblyseius gossipi* Elbadry and *Agistemus exsertus* Gonzalez (Acari, Phytoseiidae, Stigmeidae). Zeitschrift für Angewandte Entomologie, **93**: 453–456.

Yu, D.S.K., Hagley, E.A.C., and Laing, J.E. 1984. Biology of *Trichogramma minutum* Riley collected from apples on southern Ontario. Environmental Entomology, **13**: 1324–1329.

Yue, B., and Tsai, J.H. 1996. Development, survivorship, and reproduction of *Amblyseius largoensis* (Acari: Phytoseiidae) on selected plant pollens and temperatures. Environmental Entomology, **25**: 488–494.

Zaher, M.A., Wafa, A.K., and Shehata, K.K. 1969. Life history of the predatory mite *Phytoseius plumifer* and the effect of nutrition on its biology (Acarina: Phytoseiidae). Entomologia Experimentalis et Applicata, **12**: 383–388.

Zaher, M.A., Afify, A.M., and Gomaa, E.A. 1971. Survey and biology of *Agistemus exsertus* Gonzalez in U.A.R., with description of the immature stages (Stigmaeidae: Acarina). Zeitschrift für Angewandte Entomologie, **67**: 272–279.

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