# Effects of Temperature on the Development and Survival of *Nabis americoferus* and *N. roseipennis* (Hemiptera: Nabidae)

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**ABSTRACT** The developmental rates of *Nabis americoferus* Carayon and *N. roseipennis* Reuter were determined at eight constant temperatures. *N. americoferus* developed more rapidly from egg to adult than *N. roseipennis* at 18, 21, 24, 27, 30, and 33°C, but there was no difference at 15°C. Development was not completed at 36°C. The developmental threshold temperature was calculated to be about 11°C for both species; degree-day calculations suggest that three generations per year are probable for each species in Kentucky.

NABIDS ARE abundant predators in many agricultural habitats (Shepard et al. 1974, Irwin and Shepard 1980, Dinkins et al. 1970, Pitre et al. 1978, Pimentel and Wheeler 1973, Benedict and Cothran 1975). Nevertheless, the population dynamics of most nabid species are not well known. Possible manipulation of these predators and future inclusion in pest management strategies require an understanding of their bionomics.

Aspects of the biology and behavior of many nabid species were briefly described by Harris (1928). However, detailed developmental studies under controlled conditions are lacking for many nabid species. Our study was undertaken to describe better the influence of temperature on survival and development of *Nabis americoferus* (Carayon) and *N. roseipennis* Reuter, the two most common nabid species in soybean and alfalfa fields in Kentucky (Braman and Yeargan, unpublished data).

## Materials and Methods

Laboratory colonies of *N. americoferus* and *N. roseipennis* were initiated with specimens collected near Lexington, Ky., and maintained as described by Sloderbeck and Yeargan (1983). They were fed eggs of the tobacco budworm, *Heliothis virescens* (F.), from a colony maintained by methods similar to those used by Ignoffo (1965). Developmental periods of *N. americoferus* and *N. roseipennis* were recorded for eight constant temperatures: 15, 18, 21, 24, 27, 30, 33, and 36°C. Both species were reared concurrently at each temperature to minimize variation in experimental conditions that would prevent accurate comparison of the two species. A photoperiod of LD15:9 was used in all experiments. Relative humidity was held at or near 100% within the rearing chambers.

Adult nabids from the laboratory colonies were placed in environmental chambers and allowed to oviposit in green beans. Oviposition occurred at the temperature at which subsequent development was monitored, except for the 15°C experiment. Because of the difficulty in obtaining sufficient numbers of eggs at that temperature, eggs for the 15°C experiment were oviposited by adults held at ca. 24°C. Beans containing eggs deposited during a 24-h period were placed in 59-ml plastic cups. Each cup was supplied with a piece of damp filter paper or moist cotton to prevent desiccation, and sealed with Parafilm M. Upon emergence, nymphs were transferred to individual, ventilated 59-ml cups. Nymphs were fed daily with an excess of tobacco budworm eggs and supplied with a section (4-6 cm) of green bean or moist cotton to serve as a moisture source. Development was monitored daily during the 21 and 24°C experiments, and twice daily during the 15, 18, 27, 30, 33, and 36°C experiments. The date and time that each egg hatched and nymph molted, as indicated by presence of exuviae, was estimated as the midpoint of the period (i.e., between observations) during which the event occurred.

Duration of development at each temperature was compared between *N. americoferus* and *N. roseipennis* and between males and females of each species. Student's *t* test was used to test for significant differences.

## Results and Discussion

Both *N. americoferus* and *N. roseipennis* completed development at temperatures between 15 and 33°C (Table 1). The extreme temperatures (15, 18, and 33°C) had adverse effects, including high mortality and retarded development, on both species. A constant temperature of 36°C proved fatal to all *N. roseipennis* eggs. While *N. americoferus* first instars emerged from the eggs (38.8% survival), they did not survive beyond 24 h at 36°C. At 18, 21, 24, 27, 30, and 33°C, *N. americoferus*

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Table 1. Duration in days of the immature stages of *N. americoferus* and *N. roselpennis*

| Temp | Stage | *N. americoferus* | | *N. roselpennis* | |
|---|---|---|---|---|---|
| | | $\bar{x}$ ± SE | (n) | $\bar{x}$ ± SE | (n) |
| 15°C | Egg | 31.4 ± 0.2a | (143) | 35.1 ± 0.2b | (91) |
| | Instar I | 12.2 ± 0.3a | (64) | 13.1 ± 0.3a | (57) |
| | Instar II | 11.0 ± 0.3a | (50) | 10.1 ± 0.3b | (49) |
| | Instar III | 13.5 ± 0.4a | (31) | 11.0 ± 0.2b | (40) |
| | Instar IV | 15.0 ± 0.5a | (21) | 13.0 ± 0.4b | (31) |
| | Instar V | 29.0 ± 1.0a | (3) | 24.6 ± 0.6b | (10) |
| | Total | | | | |
| | Nymphal period | 80.0 ± 1.8a | (3) | 71.4 ± 1.6b | (10) |
| | Developmental period | 116.1 ± 3.5a | (0&8, 3&9) | 108.2 ± 2.1a | (6&8, 4&9) |
| 18°C | Egg | 20.9 ± 0.1a | (126) | 26.7 ± 0.1b | (82) |
| | Instar I | 9.7 ± 0.3a | (73) | 10.8 ± 0.4b | (58) |
| | Instar II | 8.6 ± 0.3a | (57) | 7.8 ± 0.4a | (49) |
| | Instar III | 8.4 ± 0.2a | (49) | 8.4 ± 0.4a | (48) |
| | Instar IV | 8.8 ± 0.2a | (41) | 9.4 ± 0.3a | (45) |
| | Instar V | 14.7 ± 0.5a | (35) | 15.8 ± 0.2a | (36) |
| | Total | | | | |
| | Nymphal period | 49.1 ± 1.0a | (35) | 49.3 ± 0.5a | (36) |
| | Developmental period | 70.0 ± 1.0a | (1&8&, 17&9) | 75.9 ± 0.5b | (2&8&, 1&9&) |
| 21°C | Egg | 13.1 ± 0.1a | (59) | 16.2 ± 0.1b | (60) |
| | Instar I | 4.6 ± 0.1a | (50) | 5.8 ± 0.1b | (52) |
| | Instar II | 4.0 ± 0.1a | (49) | 4.6 ± 0.1b | (46) |
| | Instar III | 4.1 ± 0.1a | (47) | 4.5 ± 0.1b | (43) |
| | Instar IV | 4.8 ± 0.1a | (45) | 5.5 ± 0.1b | (42) |
| | Instar V | 7.8 ± 0.1a | (40) | 9.2 ± 0.1b | (38) |
| | Total | | | | |
| | Nymphal period | 25.2 ± 0.1a | (40) | 29.2 ± 0.3b | (38) |
| | Developmental period | 38.3 ± 0.3a | (17&8, 23&9) | 45.3 ± 0.3b | (22&8, 16&9) |
| 24°C | Egg | 10.0 ± 0.1a | (49) | 12.8 ± 0.1b | (40) |
| | Instar I | 4.0 ± 0.1a | (43) | 4.5 ± 0.1b | (35) |
| | Instar II | 3.0 ± 0.1a | (41) | 3.8 ± 0.1b | (33) |
| | Instar III | 3.2 ± 0.1a | (40) | 4.1 ± 0.1b | (31) |
| | Instar IV | 3.5 ± 0.1a | (39) | 4.3 ± 0.1b | (29) |
| | Instar V | 5.9 ± 0.1a | (39) | 7.3 ± 0.2b | (27) |
| | Total | | | | |
| | Nymphal period | 19.7 ± 0.2a | (39) | 24.0 ± 0.3b | (27) |
| | Developmental period | 29.6 ± 0.2a | (17&8, 22&9) | 36.8 ± 0.2b | (11&8, 16&9) |
| 27°C | Egg | 7.3 ± 0.1a | (101) | 10.1 ± 0.0b | (116) |
| | Instar I | 3.1 ± 0.1a | (84) | 4.1 ± 0.1b | (96) |
| | Instar II | 2.4 ± 0.1a | (76) | 3.1 ± 0.1b | (90) |
| | Instar III | 2.6 ± 0.1a | (71) | 3.2 ± 0.1b | (88) |
| | Instar IV | 3.2 ± 0.1a | (70) | 3.6 ± 0.1b | (87) |
| | Instar V | 5.4 ± 0.2a | (68) | 6.9 ± 0.2b | (83) |
| | Total | | | | |
| | Nymphal period | 16.8 ± 0.3a | (68) | 21.0 ± 0.3b | (83) |
| | Developmental period | 24.0 ± 0.3a | (30&8, 38&9) | 30.7 ± 0.4b | (41&8, 42&9) |
| 30°C | Egg | 5.7 ± 0.4a | (161) | 8.3 ± 0.1b | (115) |
| | Instar I | 2.9 ± 0.1a | (89) | 3.5 ± 0.1b | (103) |
| | Instar II | 2.6 ± 0.1a | (71) | 2.2 ± 0.1b | (100) |
| | Instar III | 2.8 ± 0.1a | (65) | 2.4 ± 0.1b | (99) |
| | Instar IV | 3.6 ± 0.1a | (62) | 3.2 ± 0.1b | (98) |
| | Instar V | 5.0 ± 0.2a | (57) | 5.2 ± 0.1a | (97) |
| | Total | | | | |
| | Nymphal period | 16.9 ± 0.3a | (57) | 16.4 ± 0.1a | (97) |
| | Developmental period | 22.4 ± 0.2a | (37&8, 20&9) | 24.6 ± 0.2b | (61&8, 36&9) |
| 33°C | Egg | 5.8 ± 0.1a | (237) | 8.5 ± 0.1b | (173) |
| | Instar I | 2.8 ± 0.1a | (94) | 4.5 ± 0.2b | (44) |
| | Instar II | 2.0 ± 0.1a | (73) | 3.1 ± 0.3b | (24) |
| | Instar III | 2.2 ± 0.1a | (70) | 3.5 ± 0.4b | (17) |
| | Instar IV | 2.3 ± 0.1a | (62) | 3.8 ± 0.3b | (13) |
| | Instar V | 4.1 ± 0.1a | (52) | 6.3 ± 0.9b | (4) |
| | Total | | | | |
| | Nymphal period | 13.2 ± 0.2a | (52) | 16.8 ± 0.1b | (4) |
| | Developmental period | 18.6 ± 0.3a | (30&8, 22&9) | 27.8 ± 1.1b | (3&8, 1&9) |

Means, within a row, followed by the same letter are not significantly different ($P > 0.05$).

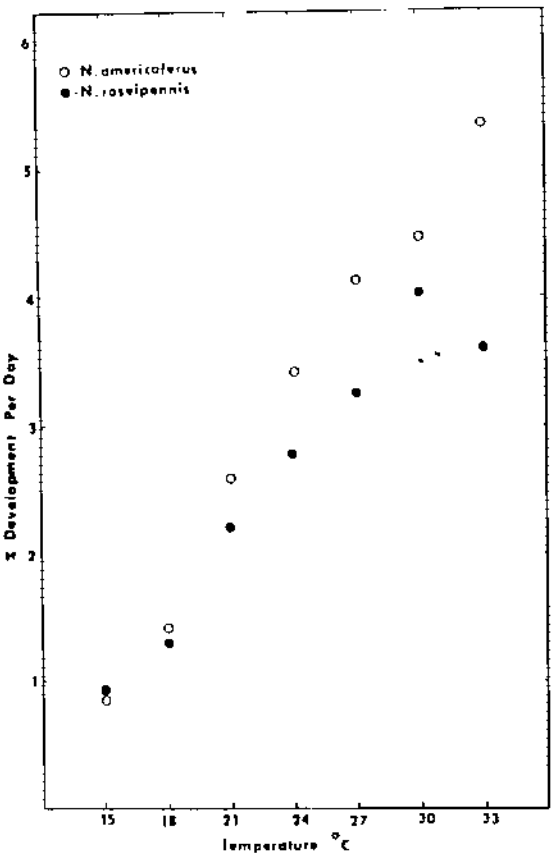


Fig. 1. Relationship between temperature and rate of development of *N. americoferus* and *N. roseipennis* from egg to adult.

developed significantly more rapidly than *N. roseipennis* (Table 1). At 15°C, however, *N. americoferus* eggs developed faster than those of *N. roseipennis*, while the nymphs of *N. roseipennis* developed faster than those of *N. americoferus*. Thus the total developmental periods for the two species at this temperature were not significantly different ($P > 0.05$). At 18°C, although the nymphal period of development was not significantly different ($P > 0.05$) between the two species, *N. americoferus* eggs completed development in a significantly ($P < 0.05$) shorter period than did those of *N. roseipennis*. Median developmental times closely approximated mean duration of development at all temperatures except 15°C. *Nabis americoferus* and *N. roseipennis* required total median developmental periods of 113.1 and 114.0 days, respectively, at that temperature. At temperatures below 30°C no significant differences ($P > 0.05$) or consistent trends in developmental times between males and females of either species were observed. Significant differences ($P < 0.05$) in developmental times between males and females of *N. americoferus* were observed at 30°C (males, 22 days; females, 23.2 days) and 33°C (males, 18.4 days; females, 20.2 days). Both sexes of *N. roseipennis* required the same amount of time to develop, except at 30°C (males, 24 days; females, 25.6 days). In all cases where differences were observed, males developed more rapidly than females.

Survivorship of the eggs was low at most temperatures. The high mortality was primarily due to fungal growth on the oviposition substrate and probably does not accurately reflect normal egg mortality. Survivorship during the egg stage ranged from 0 (*N. roseipennis*, 36°C) to 73% (*N. americoferus*, 27°C). The values for $n$ in Table 1 represent the number of individuals in the cohort that survived to the completion of a given stage. In this study, they also represent the number of individuals beginning the succeeding stage. Thus, except for the egg stage, age-specific mortality can be calculated by comparing the number of individuals entering and completing a given stage. Nymphal survivorship was high at the intermediate temperatures 21, 24, 27, and 30°C, with from 63 to 84% of the first instars surviving to adulthood. All stages suffered high mortality at 15, 18, and 33°C.

Because nabid species determination is difficult, especially for the immature stages, estimates of seasonal population trends often have been reported at the generic level. Furthermore, studies of predator abundance in annual crops have usually concentrated on population events within the growing season for that crop, rather than for the entire year (e.g., Shepard et al. 1974, McPherson et al. 1982). Therefore, reports of the number of generations per year for particular *Nabis* species are scarce, and usually have resulted from field studies in perennial agroecosystems. For example, Stoner et al. (1975) reported that there were probably five generations of both *N. americoferus* and *N. alternatus* Parshley in alfalfa near Tucson, Ariz. As described below, we used the developmental data from our study to estimate the number of possible generations for *N. americoferus* and *N. roseipennis* in Kentucky.

Extrapolation of the linear portions of the temperature-development curves (Fig. 1, 15–30°C for *N. roseipennis* and 15–33°C for *N. americoferus*) allowed estimation of developmental threshold temperatures for egg, nymphal, and total development. These threshold temperatures were 11.9 (egg), 10.8 (nymphal), and 11.3°C (total development) for *N. americoferus*, and 11.2 (egg), 10.7 (nymphal), and 11.0°C (total development) for *N. roseipennis*.

The average calculated thermal requirements (Celsius degree-days) for the temperatures 15, 18, 21, 24, 27, and 30°C were, respectively, 429.6, 469.0, 371.5, 370.8, 376.8, and 418.9 for *N. americoferus* (threshold 11.3°C); and 432.8, 531.3, 453.0, 468.0, 491.2, and 467.4 for *N. roseipennis* (threshold 11.0°C). At 33°C, *N. americoferus* required 403.6 degree-days to develop from egg to

adult. The overall average thermal requirements for temperatures between 15 and 30°C were 473.9 degree-days for *N. roseipennis*, and for temperatures between 15 and 33°C, 405.7 degree-days for *N. americoferus*. Using the calculated threshold temperatures for the two species as bases, the average number of degree-days accumulated each year for the past four years (1980–1983) near Lexington, Ky., ranged from 1,900 to 2,101 (threshold 11.0°C) and from 1,844 to 2,047 (threshold 11.3°C) from January through October. Our unpublished field data collected near Lexington, Ky., indicate that development of the final generation of both species is completed by the end of October. When an estimate of the preoviposition periods of the two species (8–10 days for each species at 24°C) is combined with the calculated degree-days required to complete development, the resulting values indicate that there are at least three full generations per year for both species in Kentucky. Preliminary field studies in alfalfa near Lexington are consistent with these estimates (Braman and Yeargan, unpublished data).

Perkins and Watson (1972) studied the development of *N. alternatus* at 28°C with a 15 h photophase and 59% RH. At that temperature *N. alternatus* spent 6.5 days in the egg stage and required an average of 16.1 days to complete nymphal development. Survival during the egg stage was approximately 79%. Hornchan et al. (1976) observed an average nymphal duration for *T. capsiformis* (Germar) of 18.0 days (males) and 22.4 days (females) at between 26 and 28°C, 60 and 70% RH with a 15 h photophase. Incubation of the egg required an average of 7.6 days, with 78% survivorship. The average rate of development of *N. americoferus* (egg, 7.3 days; nymph, 16.8 days; 27°C) therefore appears similar to that of *N. alternatus* and *T. capsiformis*. *Nabis roseipennis*, however required longer to mature (egg, 10.1 days; nymph, 21.0 days; 27°C) than did *N. americoferus* (Table 1), and likewise appears to require a longer developmental period than *N. alternatus* or *T. capsiformis*. *Nabis roseipennis* had slightly lower mortality at 15 and 18°C, and much higher mortality at 33°C, than did *N. americoferus* (Table 1); also, 36°C proved more detrimental to eggs of *N. roseipennis* than to those of *N. americoferus*. These observations suggest that *N. americoferus* is best adapted to a slightly warmer range of temperatures than that for *N. roseipennis*.

The implications of differences in survival and developmental rates of *N. americoferus* and *N. roseipennis* at certain temperatures are not fully understood. We have observed that both species will oviposit in alfalfa fields near Lexington, Ky., as early as the first week of March. Adults of the final, overwintering generation of *N. americoferus* mature slightly earlier in the fall than do those of *N. roseipennis* (Braman and Yeargan, unpublished data). The apparent adaptation of *N. roseipennis* to cooler temperatures may facilitate the completion of the final generation of the species under autumn conditions each year. Alternatively, differences in adaptation to temperature may reflect behavioral segregation of the two species among microhabitats (e.g., relatively exposed versus shaded sites). Harris (1928) suggested that *N. roseipennis* adults prefer more shady situations than does *N. americoferus* (= *N. ferus*). Differences in duration of development may also serve to separate the two species in time, thus reducing potential competition.

The data reported here are useful for predicting the phenology of these common predators as a function of temperature. This is an important aspect of efforts to determine their impact on pest populations, because it allows one to determine the degree of seasonal synchrony with potential prey populations.

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