Biology of *Peregrinus maidis* with Descriptions of Immature Stages (Homoptera: Delphacidae)

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ABSTRACT The corn delphacid, *Peregrinus maidis* (Ashmead), a vector of two economically important diseases of maize, was reared, from eggs to adults, at five constant temperatures, 10, 15.6, 21.1, 26.7, or 32.2°C, with a 12:12 (L:D) photoperiod. Developmental times for each instar ranged from 10 to 24.3 days for instars one through four at 10°C, 7.7–13.5 days for instars one through six at 15.6°C, 4.6–6.0 days for instars one through five at 21.1°C, 3.1–4.4 days for instars one through five at 26.7°C, and 1.9–16.8 days for instars one through four at 32.2°C. Both male and female longevities were highest at 15.6°C and lowest at 10°C. Number of eggs laid per day per female was (mean ± SD) 19.6 ± 2.5, number of eggs per female per life was (mean ± SD) 605 ± 190.1, preoviposition period was 3–6 days, and the oviposition period was 11–48 days. The five instars of *P. maidis* are described and illustrated.

Peregrinus maidis (Ashmead) has been much studied; Metcalf (1943) listed 133 papers up to 1942. Since that time this delphacid has been implicated as a vector of at least two viral diseases of maize (*Zea mays* L.), and is of particular economic importance in the lowland humid tropics. It has even been suggested that its introduction into Central America resulted in the collapse of the classic Mayan civilization (Brewbaker 1979).

P. maidis is pantropical, having been recorded from most tropical regions (Metcalf 1943). In the United States it has been recorded from Washington, D.C., south to Florida, and west to Ohio and Texas (Metcalf 1943). Some of these records may be in error, having been published before the use of genitalic features in delphacid identification.

P. maidis is the only known vector of two major viral diseases of maize, maize mosaic virus (Nault & Knoke 1981) and maize stripe virus (Tsai 1975). The former is a tropical and subtropical disease described from Hawaii in 1921 by Kunkel and confirmed by Bradfute & Tsai (1983) in southern Florida. Maize stripe virus, also a tropical and subtropical disease, has been known to occur in southern Florida since 1974 (Tsai 1975), where it is part of a severe corn disease complex (Falk & Tsai 1983a).

Although considerable work on transmission by *P. maidis* of these two viruses has been done (Tsai & Zitter 1982, Falk & Tsai 1983a,b), very little is known about its biology and ecology (Nault 1984). This paper reports the biology and describes the immature stages of *P. maidis*.

Materials and Methods

P. maidis eggs were excised from the midribs of corn plants and placed on cut leaf pieces of corn (*Zea mays* L. var. Saccharata 'Guardian') and allowed to hatch. Newly hatched nymphs were placed in individual petri dishes (10 cm) containing fresh leaf pieces. The petri dishes were then covered with a plastic bag to maintain high humidity and placed in an environmental chamber at one of five temperatures, 10, 15.6, 21.1, 26.7, or 32.2°C and a light cycle of 12:12 (L:D) photoperiod. Daily observations were made and fresh leaf pieces were introduced every 2 days. Recorded were the dates of molting, length of stadia, mortality, and adult longevity at each of the five temperatues. A regression analysis and analysis of variance were used to determine whether temperature had an effect on developmental time.

Upon adult ecdysis, 17 pairs (one male and one female) of *P. maidis* were maintained at 26.7°C on individual corn plants at the 5- to 6-leaf stage and covered by a plastic cage. Pairs were removed daily to new plants, which were then dissected for egg counts. We recorded the number of eggs laid per female each day, number of eggs laid per female in a lifetime, and length of preoviposition and oviposition periods.

Specimens to be described were obtained from laboratory stock and were preserved in 70% ethyl alcohol. Several specimens of each instar were cleared in 10% KOH to observe certain obscure features. The first instar is described in detail, but only major changes from previous instars are described for subsequent instars. Comparative statements refer to previous instars (e.g., "more numerous"). Dimensions of eggs and nymphs are expressed in millimeters as mean ± SE. Length of nymphs was measured from tip of vertex to tip of abdomen; thoracic length was measured along the midline from anterior margin of the pronotum to posterior margin of the metanotum; width was measured across the widest part of the body.

Results

Biology of *P. maidis*. Rearing at 10 and 32.2°C resulted in the loss of fifth instars. Fourth instars

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Table 1. ***P. maidis*** **development (in days; $\bar{x}$ ± SD) at various temperatures**

Life stages	Temp (°C)				
	10	15.6	21.1	26.7	32.2
1st instar					
$\bar{x}$	10.0 ± 6.3	7.7 ± 2.8	5.2 ± 1.5	4.3 ± 1.5	1.9 ± 1.1
n	44	71	49	89	67
2nd instar					
$\bar{x}$	20.2 ± 10.0	11.1 ± 2.8	4.6 ± 1.6	3.1 ± 1.4	4.2 ± 1.5
n	18	41	42	53	58
3rd instar					
$\bar{x}$	24.3 ± 10.2	10.5 ± 4.1	5.4 ± 2.3	3.3 ± 1.6	10.6 ± 5.8
n	4	25	33	39	33
4th instar					
$\bar{x}$	19.0 ± 22.6	13.5 ± 4.9	6.0 ± 2.7	3.3 ± 1.3	16.8 ± 6.4
n	2	17	26	35	6
5th instar					
$\bar{x}$		12.7 ± 6.0	6.0 ± 0.8	4.4 ± 1.2	
n		15	15	17	
6th instar					
$\bar{x}$		9.7 ± 4.0			
n		3			
Adult longevity					
$\bar{x}$	8 (♂); 1 (♀)	96.6 ± 15.6 (♂); 107.6 ± 6.2 (♀)	28.5 ± 18.9 (♂); 26.3 ± 17.8 (♀)	32.1 ± 22.5 (♂); 35.1 ± 21.3 (♀)	10 ± 4.2 (♂); 18.5 ± 3.3 (♀)
n	1 (♂); 1 (♀)	7 (♂); 7 (♀)	12 (♂); 11 (♀)	14 (♂); 21 (♀)	2 (♂); 4 (♀)

molted directly to adult. Rearing at 15.6°C resulted in supernumerary sixth instars. At 21.1 and 26.7°C, development proceeded normally with five instars. The developmental times for each stadium ranged up to 5-fold over the range of temperatures (Table 1). The effect of temperature on instar development was significant at the 0.05 level of confidence with $F_{(4,96)}$ values of 11.41, 35.08, 4.83, 2.96, and 10.21 for first through fifth instars, respectively. The regression analysis also demonstrates the effect of temperature on development with *r* values (slopes ± SE) of 0.994 (−0.2096 ± 0.698), 0.999 (−0.4135 ± 1.055), 0.996 (−0.2164 ± 0.5125), 0.906 (−0.7801 ± 0.5968), and 0.962 (−0.2243 ± 0.4052) for first through fifth instars, respectively (Fig. 1). Both male and female longevities were highest at 15.6°C and lowest at 10°C (Table 1).

The 17 pairs tested in the oviposition experiment had a mean ± SD of 19.6 ± 2.5 eggs, ranging from 15.6 to 25.1 eggs per day per female, and a mean ± SD of 605 ± 190.1 eggs, ranging from 297 to 938 eggs per female per life. The preoviposition period ranged from 3 to 6 days. The oviposition period ranged from 11 to 48 days.

Description

Adult (Fig. 2 A–E). *P. maidis* adults have been described by Ashmead (1890), Van Duzee (1897), Quaintance (1898), and Crawford (1914). Fullaway (1918), and Caldwell & Martorell (1950) partially illustrated the male genitalia. An adult macropter and brachypter are illustrated in Fig. 2 A and B and the male genitalia are shown in Fig. 2 C–F.

Immatures. Several authors have illustrated and described the eggs and nymphs but these descriptions are generally brief and unclear. Ashmead (1890) briefly described the egg and first instar and provided small, poorly detailed drawings. Quaintance (1898) published short descriptions of eggs and all instars and provided photographs of the eggs and first, second, and fourth instars. Fullaway (1918) published small, poorly detailed illustrations of eggs and first, third, and fifth instars.

Egg (Fig. 3A) (20 specimens). Length 1.06 ± 0.01, width 0.28 ± 0.01. Elongate, cylindrical, curved; narrowed at ends, anterior end somewhat knoblike, rounded; posterior end broadly rounded;

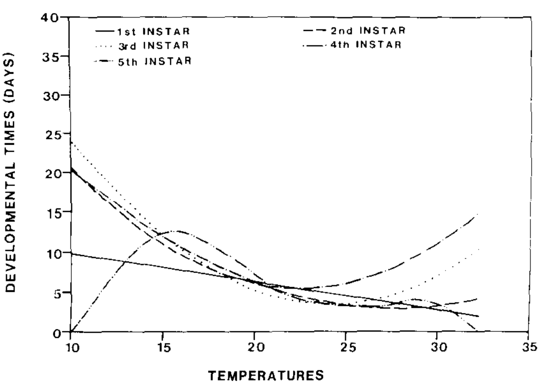

Fig. 1. Regression analysis of effect of temperature on instar development.

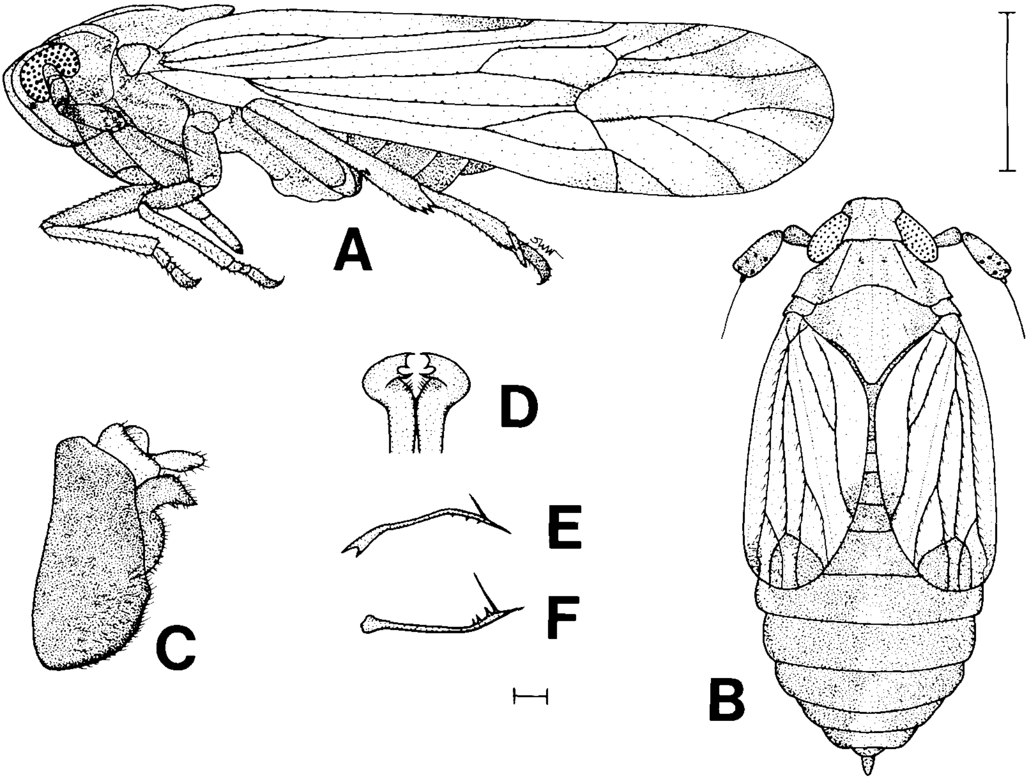

Fig. 2. *P. maidis.* A, lateral view of adult macropter; B, dorsal view of adult brachypter; C, lateral view of complete male genitalia; D, caudal view of male styles; E and F, aedeagus, left lateral (E) and ventral (F) views. Vertical bars = 0.5 mm (A and B) and 0.1 mm (C–F).

chorion translucent, smooth; white; eyespots red, with red suffusion posteriorly.

First Instar (Fig. 3B) (19 specimens). Length 1.38 ± 0.04, thoracic length 0.45 ± 0.01, width 0.39 ± 0.01. Elongate, subcylindrical, widest across mesothorax. Body white. Vertex subquadrate, anterior margin not differentiated from border with frons, latter convex, broadly rounded in lateral view; in frontal view, slightly wider than long; lateral margins carinate (outer carinae), extending ventrally to clypeal border and parallel pair of inner carinae; nine pits in two irregular rows between each outer and inner carina, two pits between each outer carina and eye (e.g., Fig. 4C). Clypeus narrowing distally, consisting of subconical basal postclypeus and cylindrical distal anteclypeus. Beak 3-segmented; segment 1 almost obscured by anteclypeus, segments 2 and 3 subequal. Eyes red. Antennae 3-segmented; scape and pedicel subcylindrical; pedicel ca. 1.5-fold length of scape; flagellum bulbous basally, filamentous distally, bulbous portion ca. ⅔ length of pedicel.

Thoracic nota divided by longitudinal middorsal line into three pairs of plates. Pronotum with each plate subrectangular, anterior and posterior margins slightly sinuate, with single row of six very obscure pits. Mesonotum with median length ca. 2-fold that of pronotum; each plate subquadrate; with two obscure pits near lateral margin and two pits in median half. Metanotum with median length ca. ⅔ that of mesonotum; with one pit. Pro- and mesocoxae elongate, posteromedially directed, metacoxae smaller, fused to metasternum. Metatibiae with three tiny black-tipped spines apically and very short, conical, apical, spinelike, moveable black-tipped spur; spur slightly longer than longest spine. Tarsi each with two tarsomeres, divisions very obscure; pro- and mesotarsomere 1 wedge-shaped; metatarsomere 1 subcylindrical, with row of four tiny black-tipped spines apically, tarsomere 2 of all legs subconical and slightly curved with pair of slender apical claws.

Abdomen 9-segmented, subcylindrical, widest across segments 3 and 4. Segment 9 elongate vertically, surrounding anus. Segments 1 and 2 with tergites reduced to obscure plates. Several segments with very obscure lateral pits on tergites.

Second Instar (Fig. 3C) (20 specimens). Length 1.64 ± 0.04; thoracic length 0.55 ± 0.01; width 0.57 ± 0.01. Frons with three pits between each outer carina and eye. Antennae with pedicel bearing two ringlike sensoria on dorsal aspect near apex; bulbous portion of flagellum ca. ½ length of pedicel. Metatibial spur ca. 2-fold length of longest apical spine or longer.

Third Instar (Fig. 3D) (20 specimens). Length

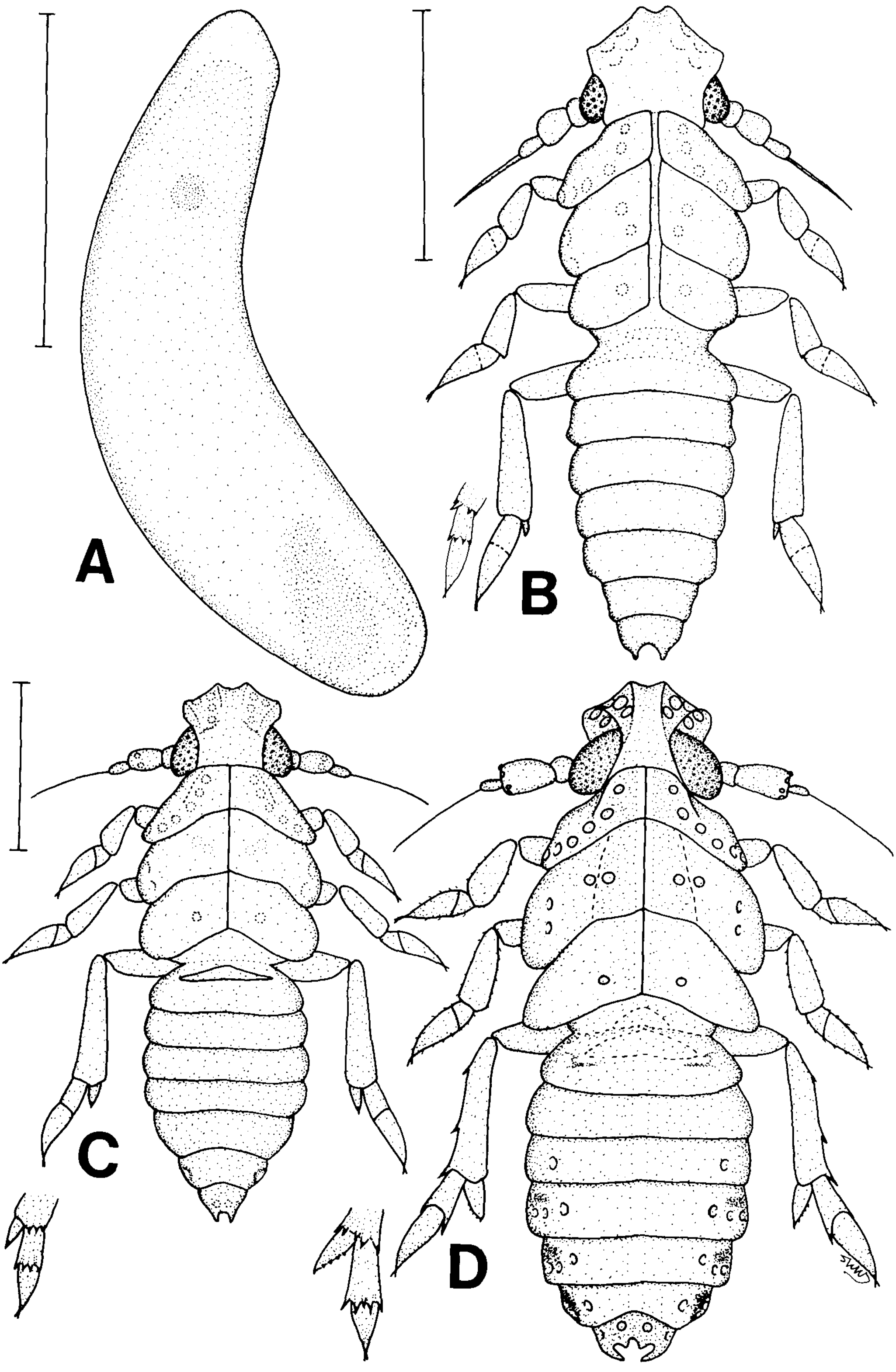

Fig. 3. *P. maidis* egg and nymphs. A, egg. B–D, nymphs with ventral aspect of distal end of metathoracic legs: B, first instar; C, second instar; D, third instar. Vertical bars = 0.5 mm.

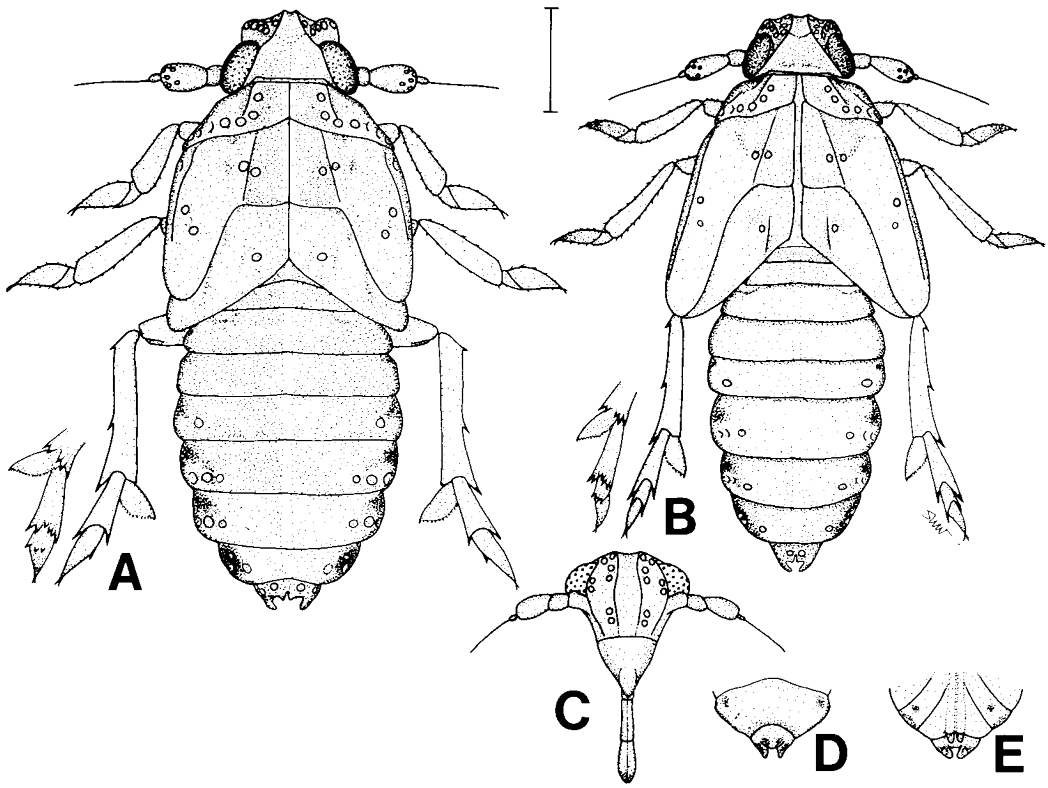

Fig. 4. *P. maidis* nymphs with ventral aspect of distal end of metathoracic legs (A and B) and fifth instar structures (C–E). A, fourth instar; B, fifth instar; C, head in anterolateral view; D and E, ventral views of distal end of male (D) and female (E) abdomens. Vertical bars = 0.5 mm.

2.26 ± 0.04; thoracic length 0.72 ± 0.01; width 0.83 ± 0.01. Frons with four obscure pits between each outer carina and eye. Antennae with pedicel bearing four ringlike sensoria on dorsal aspect near apex; bulbous portion of flagellum ca. ⅓ length of pedicel. Metatibiae with two tiny black-tipped spines on lateral aspect of shaft and transverse row of five black-tipped spines apically; spur ca. 3-fold length of longest spine, somewhat ovoid in cross section, with row of five very small black-tipped teeth on ventrolateral aspect. Metatarsomere 1 with transverse row of five black-tipped spines apically. Abdominal tergites 5 with one pit, tergites 6–9 each with three pits, lateralmost pits often not visible in dorsal view; pits present and less numerous in earlier instars but very obscure.

Fourth Instar (Fig. 4A) (18 specimens). Length 2.87 ± 0.05; thoracic length 0.93 ± 0.02; width 1.17 ± 0.02. Antenna pedicel bearing six ringlike sensoria dorsally near apex; bulbous portion of flagellum ca. ⅙ length of pedicel. Each plate of pronotum bearing weakly developed oblique longitudinal partial carina in median half with single row of seven pits. Mesonotum with each plate bearing partial oblique longitudinal carina in median ⅓; with three pits in lateral ⅓, strongly lobate laterally, each wingpad covering ca. ½–⅔ of metanotal wingpad. Metatibial spur longer, with row of 10–12 small black-tipped teeth on ventrolateral aspect, slightly flatter in cross section. Metatarsomere 1 with transverse row of six black-tipped spines apically, metatarsomere 2 partially subdivided by transverse row of three small black-tipped spines on ventral aspect near middle.

Fifth Instar (Fig. 4B) (17 specimens). Length 3.99 ± 0.10; thoracic length 1.22 ± 0.02; width 1.70 ± 0.04. Body stramineous, with slight longitudinal markings. Antenna pedicel bearing nine ringlike sensoria dorsally near apex. Mesonotal wingpads in macropter lobate, extending to apex of metanotal wingpads. Metanotal wingpads extending to abdominal tergite 3 or 4. Brachypters with wingpads like those of fourth instars as in *Megamelus davisi* Van Duzee (see Wilson & McPherson 1981). Metatibial spur longer, slightly more flattened, with row of 16–20 small black-tipped teeth on ventrolateral aspect. Metatarsi with three tarsomeres; tarsomere 1 with transverse row of seven black-tipped spines apically, tarsomere 2 with transverse row of four black-tipped spines apically, tarsomere 3 similar in size and shape to terminal tarsomere of earlier instars. Abdominal tergites 6–9 each with one black mark laterally. Females with slender, paired, partially developed sternal medial sawcase, this most evident posteriorly, with sternites strongly curved anteromedially; males lacking developing sawcase, with sternites not strongly curved anteromedially (Fig. 4 D and E). No morphological difference was noted between the fifth and supernumerary sixth instars.

Key to Instars

1. Metatarsi with 3 tarsomeres or with terminal tarsomere (2nd) bearing 3 teeth in middle on ventral aspect; pronotum with row of 7 pits on each side (Fig. 4 A and B) 2
   Metatarsi with 2 tarsomeres; pronotum with row of 6 pits on each side (Fig. 3 B–D) .. 3
2. Metatarsi with 3 tarsomeres, tarsomere 2 with apical row of 4 teeth; antennal pedicel with 9 ringlike sensoria (Fig. 4B) ... Fifth instar
   Metatarsi with 2 tarsomeres, tarsomere 2 with 3 teeth in middle on ventral aspect; antennal pedicel with 6 ringlike sensoria (Fig. 4A) .... Fourth instar
3. Metatibial spur with row of 4 teeth; metatarsomere 2 with 5 apical teeth (Fig. 3D) .... Third instar
   Metatibial spur with 1 terminal tooth; metatarsomere 2 with 4 apical teeth (Fig. 3 B and C) 4
4. Metatibial spur barely developed, <2-fold length of longest metatibial spine; thoracic width <0.5 mm (Fig. 3B) ...... First instar
   Metatibial spur well developed, >2-fold length of longest metatibial spine; thoracic width >0.5 mm (Fig. 3C) ... Second instar

Discussion

Introductions of tropical crop pests are of obvious concern to agricultural entomologists. Southern Florida offers an ideal conduit for the importation of species from the American tropics by either human activities or transport by storms or rafting. Brewbaker (1979) suggested that *P. maidis* was carried to Middle America by hurricanes. Whatever the mode of invasion, *P. maidis* is apparently well established in southern Florida and, as a vector of corn viruses, poses a threat to this crop.

Normal development occurred at only two of the five temperatures, 21.1 and 26.7°C. The optimal temperatures for *P. maidis* are 21.1 and 26.7°C. At 21.1°C nymphal developmental time is longer and adult longevity is shorter than at 26.7°C. Therefore, both temperature regimes are suitable for mass-rearing of *P. maidis* for transmission and pesticide studies. At 10°C, instar five was eliminated; total development time from egg hatch to adult averaged 73.5 days, almost 4-fold that of the optimal (26.7°C) temperature. At 15.6°C a supernumerary instar was present and total development time, 65.2 days, was ca. 3.5-fold that of the optimal temperature. At 32.2°C, instar five was again eliminated and the 33.5 days total development time was almost twice that of the optimal temperature. The underlying reason for the abnormal development observed at the highest and two lowest temperatures likely involves an asynchrony in biochemical reactions resulting from temperature stress on the insects' metabolism (Ratte 1985). An analysis of both this possibility and of any interactions among delayed maturity, nutrition, and temperature, although of interest, is beyond the scope of the present study. The upper limit of 32.2°C correlates with the low incidence of maize viruses in southern Florida in summer (J.H.T., unpublished data). When *P. maidis* is collected in the field during summer, it is always found in small numbers between the sheath and stalk or deep into the whorl of the plant, shielding itself from the extreme temperature fluctuations externally.

Several studies have shown that as temperature increases development time decreases (Kilian & Nielson 1971, Butler et al. 1983, Braman et al. 1984). We have observed a similar phenomenon; at 10.0, 15.6, 21.1, and 26.7°C nymphal developments took 73.5, 65.2, 27.2, and 18.4 days, respectively (Table 1). Because of slow development at low temperature, we have been able to maintain a large number of spare colonies of healthy and viruliferous *P. maidis* at 15.6°C without frequent transfers. No harmful effects on either insects or pathogens were noted when they were returned to 26.7°C. However, development at 32.2°C took 33.5 days, while at 26.7°C it took only 18.4 days, again illustrating the stress placed on *P. maidis* at 32.2°C. At temperatures of 26 to 43.3°C most *Bemisia tabaci* (Gennadius) (Aleyrodidae) pupae delay development until temperatures fall to 24.42°C, when development continues (Butler et al. 1983). Because *P. maidis* is a tropical and subtropical species, its presence is mostly in the Gulf Coast of the United States (Nault & Knoke 1981). Although occasionally it has been reported in Ohio, the potential for this insect to establish in the northern states is limited by a lack of overwintering plant hosts, the inability of this insect to reproduce, and high nymphal mortality (95.5%) at 10°C. Likewise, the spread of maize mosaic virus and maize stripe virus beyond the southern coastal regions of the United States is not expected.

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References Cited

Ashmead, W. H. 1890. The corn delphacid, *Delphax maidis*. Psyche 5: 321–324.

Bradfute, O. E. & J. H. Tsai. 1983. Identification of maize mosaic virus in Florida. Plant Dis. 67: 1339–1342.

Braman, S. K., P. E. Sloderbeck & K. V. Yeargan. 1984. Effects of temperature on the development and survival of *Nabis americoferus* and *N. roseipennis* (Homoptera: Nabidae). Ann. Entomol. Soc. Am. 77: 592–596.

Brewbaker, J. L. 1979. Diseases of maize in the wet lowland tropics and the collapse of classic Maya civilization. Econ. Bot. 33: 101–118.

Butler, G. D., Jr., T. J. Henneberry & T. E. Clayton. 1983. *Bemisia tabaci* (Homoptera: Aleyrodidae): development, oviposition, and longevity in relation to temperature. Ann. Entomol. Soc. Am. 76: 310–313.

Caldwell, J. S. & L. F. Martorell. 1950. Review of the Auchenorhynchous Homoptera of Puerto Rico. II. The Fulgoroidea except Kinnaridae. J. Agric. Univ. P.R. 34: 133–269.

Crawford, D. L. 1914. A contribution toward a monograph of the homopterous insects of the family Delphacidae of North and South America. Proc. U.S. Natl. Mus. 46: 557–640.

Falk, B. W. & J. H. Tsai. 1983a. Assay for maize stripe virus-infected plants by antiserum produced to a purified noncapsid protein. Phytopathology 73: 1259–1262.

1983b. Physicochemical characterization of maize mosaic virus. Phytopathology 73: 1536–1539.

Fullaway, D. T. 1918. The corn leafhopper (*Peregrinus maidis* Ashm.). Bull. Board Comm. Agric. For. Hawaii Div. Entomol. 4: 3–16.

Kilian, L. & M. W. Nielson. 1971. Differential effects of temperature on the biological activity of four biotypes of the pea aphid. J. Econ. Entomol. 64: 153–155.

Kunkel, L. O. 1921. A possible causative agent for the mosaic disease of corn. Hawaii. Sugar Plant. Assoc. Exp. Stn. Bull. Bot. Ser. 3: 44–58.

Metcalf, Z. P. 1943. General catalogue of the Hemiptera, fasc. IV. Fulgoroidea, part 3, Araeopidae (Delphacidae). Smith College, Northhampton, Mass.

Nault, L. R. 1984. A report from chairman of vector subject matter committee. Maize Virus Dis. Newsl. 1: 65.

Nault, L. R. & J. K. Knoke. 1981. Maize vectors, pp. 77–84. *In* D. T. Gordon, J. K. Knoke, & G. E. Scott [eds.], Virus and viruslike diseases of maize in the United States. South. Coop. Ser. Bull. 247.

Quaintance, A. L. 1898. The corn *Delphax* (*Delphax maidis*, Ashmead). Bull. Fla. Agric. Exp. Stn. 45: 61–67.

Ratte, H. T. 1985. Temperature and insect development, pp. 33–66. *In* K. H. Hoffman [ed.], Environmental physiology and biochemistry of insects. Springer, New York.

Tsai, J. H. 1975. Occurrence of a corn disease in Florida transmitted by *Peregrinus maidis*. Plant Dis. Rep. 59: 830–833.

Tsai, J. H. & T. A. Zitter. 1982. Transmission characteristics of maize stripe virus by the corn delphacid. J. Econ. Entomol. 75: 397–400.

Van Duzee, E. P. 1897. A preliminary review of the North American Delphacidae. Bull. Buffalo Soc. Nat. Sci. 5: 225–261.

Wilson, S. W. & J. E. McPherson. 1981. Life history of *Megamelus davisi* with descriptions of immature stages. Ann. Entomol. Soc. Am. 74: 345–350.

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