THE INTERACTION OF TEMPERATURE AND BIOTYPE ON DEVELOPMENT OF THE GREEN PEACH APHID, *MYZUS PERSICAE* (SULZ.)[1,2]

M.E. Whalon and Z. Smilowitz

Abstract

Thermal requirements per developmental stage, offspring production, and percent survival of three isolates of the green peach aphid, *Myzus persicae* (Sulz.), were determined over a range of constant temperatures from 12.4°-29.4°C. Isolates were collected from Pennsylvania, Maine, and Washington State potato producing regions. Offspring produced, survival, and thermal requirements were not different for all three isolates. Offspring production increased from 12.4°-15.6°C and then decreased as temperature increased. Percent survival averaged 78.2% except at 29.4°C where only 26.7% survived to reproduce. Thermal requirements, with 4°C as the lower developmental threshold, were 25.2, 27.1, 30.9, 30.7, 20.4, 74.2, 201.6 and 135.7 degree days, respectively, for instars 1-4, prereproductive adults, reproductive adults, longevity, and generation time. Data were used as the basis for a computer forecast system to predict aphid population development in potato fields.

Resumen

Los requerimientos termales por estadio de desarrollo, la producción de descendientes y el porcentaje de supervivencia de tres aislamientos del áfido *Myzus persicae* (Sulz.), fueron determinados para un rango de temperaturas constantes desde 12.4° hasta 29.4°C.Los aislamientos fueron colectados en las regiones productoras de papa de los estados de Pennsylvania, Maine y Washington. Los descendientes producidos, la supervivencia y los requerimientos termales fueron iguales para los tres aislamientos. La producción de descendientes aumentó de 12.4° a 15.6°C y luego disminuyó conforme se aumentó la temperatura. El porcentaje de supervivencia promedió 78.2% excepto a 29.4°C donde solamente sobrevivieron 26.7%. Los requerimientos termales con 4°C como la temperatura más baja para desarrollo fueron 25.2, 27.1, 30.9, 30.7, 20.4, 74.2, 201.6 and 135.7

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[1]Pesticide Research Laboratory and Graduate Study Center and Department of Entomology, The Pennsylvania State University, University Park, Pennsylvania 16802.
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grados por día para estadios de 1-4, adultos prereproductivos, adultos reproductivos, longevidad y tiempo de generación, respectivamente. Los datos fueron usados como la base para un sistema computarizado de predicción para predecir el desarrollo de la población de áfidos en cultivos de papa.

Introduction

The green peach aphid (GPA), *Myzus persicae* (Sulz.), is one of the most destructive insects attacking potatoes throughout the world (10). GPA exhibit considerable life-cycle and biotype variation (4, 5, 7, 8, 14). Biotypes have been associated with host plant, stem mother (parthenogenetic reproduction), and environmental parameters (10). An integrated pest management program based on a temperature-dependent model, 'GPA-CAST,' (16, 17) which forecasts field populations, is being implemented in Pennsylvania. GPA development is predicted using thermal requirements calculated for each stage in Degree Days (DD) above a lower developmental threshold. Part of the model originated from data derived from three GPA isolates; Pennsylvania (PA), Washington (WA) and Maine (ME). The rationale for investigating isolates was to extend the model's scope of application. This is a report on the interaction of temperature and biotype on GPA development, reproduction, and survival.

Materials and Methods

The Pennsylvania (PA) isolate originated from a parthenogenetic GPA which was field collected from potato plants, *Solanum tuberosum* L. var. Katahdin, in 1976 at The Pennsylvania State University experimental farm at Rock Springs. The Washington (WA) isolate originated from a parthenogenetic GPA from var. Russet Burbank in 1976, at the USDA-ARS, Yakima Agriculture Research Laboratory. The Maine (ME) isolate was obtained from var. Katahdin in 1976 at the USDA-ARS, N.E. Plant, Soil and Water Laboratory, Orono, ME.

The aphids were isolated in 0.5×0.5×.05 m cages (9) and maintained in different environmental chambers. Experimental aphids were cloned from a single female GPA from each isolate. It was assumed that this procedure would assure uniform genetic, physiological, and sexual characteristics. Clones were maintained on potato plants, *S. tuberosum* var. Katahdin, at 25±1°C, 80% rh, 16L:8D photoperiod with 2 20-watt cool fluorescent (~10,000 lux) lights. An adult female aphid from an isolate was placed on the abaxial side of a 1.5 cm dia. potato leaf disc floating in Coon's (6) nutrient solution contained in a petri dish. After 10 h oviposition time, the adult and all but one 1st instar nymph were removed from the petri dish. The remaining aphid was monitored at 12 h intervals and its developmental history (longevity, instar periods, generation time, reproductive period, and offspring produced) were recorded. Degree days for each half day (12 h) observation period were equal to the treatment temperature minus the lower threshold (4°C). Each treatment was replicated 3 times; a total of 108 aphids per isolate was reared in each temperature regime. The seven constant temperature treatments (12.8°, 15.6°, 18.3°, 21.0°, 23.9°, 26.7° and 29.4±C) between the GPA upper and lower developmental thresholds (15) were arranged in a Youden square (11). All data were submitted to analysis of variance with the SAS General Linear Model procedure (3) and least squares regression techniques where appropriate.

Potato plants were grown under controlled conditions (25±1°C, 80% rh, 16L:8D, 10,000 Lux and 5-10-5 fertilizer) for uniformity. Because GPA prefer senescent potato tissue (10), leaf discs were cut from the bottom one-third of the potato plants. Discs were replaced at 50DD intervals in all temperature regimes to ensure uniform aphid nutrition throughout the experiment.

Results and Discussion

Offspring – The number of offspring produced per aphid increased from 12.8°C to 15.6°C and then decreased as temperature increased. This peak in offspring production was also observed by Barlow (2). Analysis of variance demonstrated no difference ($P \leq 0.05$) between total numbers of offspring produced from different isolates within the same temperature. Mean offspring produced per aphid for pooled isolates from the lowest to highest temperature were 21.8, 33.2, 29.8, 27.6, 25.2, 21.8 and 13.8 respectively. Offspring produced at 21.1°C (27.6/aphid) were similar to reproduction reported by MacGillivray and Anderson (9). A mean of 6.5±3.6 DD was required to produce one offspring over all temperatures and isolates.

Survival – Development of GPA to production of offspring occurred at all temperatures, but at 29.4°C, only 26.7% of the aphids survived to reproduce (Table 1). At the lowest temperature, 75.2% survived. The

TABLE 1. —*Percentage survival from birth to production of first offspring for three isolates, Pennsylvania (PA) Washington (WA) and Maine (ME), of the green peach aphid.*

Temp. °C	REP 1[a]			REP 2			REP 3		
	PA	WA	ME	PA	WA	ME	PA	WA	ME
12.8	83	76	68	66	66	76	83	83	76
15.6	83	83	76	76	76	66	83	92	83
18.3	83	76	68	58	92	58	92	76	76
21.1	76	76	68	58	58	66	58	66	58
23.9	93	93	83	76	93	93	68	93	93
26.7	83	76	83	76	83	76	83	93	93
29.4	8	33	8	25	50	58	8	25	25

[a]108 aphids/replicate or 36/isolate/replicate.

intermediate temperatures averaged 78.2% with the greatest survival occurring at 23.9°C, 87.2%. Mortality occurred most often in instar 4 except at the highest temperature, where few individuals lived beyond instar 3. No significant differences (P≤0.05) in mortality were found between isolates across temperatures. Estimates of survival may have been adversely affected by the aphids' behavior and the experimental apparatus. At the highest temperature (29.4°C) aphids were observed crawling off the leaf discs and into the nutrient solution, thus mortality was in part due to drowning.

Developmental Thermal Requirements – DD requirements for stage development were equal to the summation of the experimental temperature minus the lower developmental threshold per 24 h. The upper and lower developmental thresholds, 30 and 4± 1°C respectively, were determined by Whalon and Smilowitz (15). Thermal requirements when measured in DD are assumed to be constant across temperatures except at extremes where the thermal units-temperature relationship is curvilinear (13).

No significant regressions (P≤0.05) relating PA, WA and ME prereproductive stages (instars 1-4 and prereproductive adults) and temperature were found (Table 2). These results indicated that DD required to complete a prereproductive developmental stage were constant over the treatment

TABLE 2. — *Regression equations*[a] *between developmental stages measured in degree days centigrade over seven constant temperatures for three isolates of the green peach aphid.*

Life stage	Equations[b] PA isolate	WA isolate	ME isolate	All isolates[d]
Instar 1	Y= 22.6−0.38X	Y= 23.0−0.43X	Y= 25.3−0.58X	Y= 24.0−0.36X
2	Y= 23.1+0.86X	Y= 22.8+1.20X	Y= 28.5−0.42X	Y= 25.1+0.72X
3	Y= 26.2+0.70X	Y= 29.6+1.40X	Y= 26.9+0.65X	Y= 27.9+0.91X
4	Y= 26.6−2.20X	Y= 30.8−2.70X	Y= 34.0−1.50X	Y= 30.8−2.10X
Adult				
Prereproductive	Y= 6.6+0.78X	Y= 8.9+0.49X	Y= 7.4+1.10X	Y= 7.4+0.72X
Reproductive	Y= 93.4−1.70X	Y=113.0−4.90X[c]	Y= 93.3−1.90X	Y= 96.1+1.82X
Longevity	Y=205.0−2.10X	Y=228.0−3.20X[c]	Y=211.0−2.20X	Y=209.6−2.40X
Generation	Y=100.0−0.70X	Y=122.0−0.75X	Y=101.0−0.75X	Y=111.0−0.72X

[a]Y=Degree days for development; X=Temperature
[b]PA=Pennsylvania, WA=Washington, ME=Maine and All=pooled isolates.
[c]Significant (P≤0.05) regressions, i.e. 95% confidence interval about the 'β' did not contain zero.
[d]Data from 29.4°C removed from pooled isolates.

temperatures. Means representing each isolate's DD requirements per developmental stage were obtained. Duncan's new multiple range mean separation test demonstrated no difference (P≤0.05) between these means.

Since temperature and isolate effects on DD requirements per stage were not significant, a mean was used to represent the pooled isolates' DD requirements per developmental stage (Table 3). Duncan's new multiple range procedure was used to separate these means. An overall mean (28.5±2.7 DD) representing the DD requirements for all prereproductive stages was calculated because no significant differences ($P \leq 0.05$) were found between these stages. This overall mean was less than the DD requirements reported by Barbagallo et al. (1) for instars 1-4 (3.1. DD), but no standard deviations were reported.

TABLE 3. — *Pooled mean duration in degree days centigrade per developmental stage for three isolates of green peach aphid.*

	Developmental Stages							
	Instars				Adult			
Statistic	1	2	3	4	Prereproductive	Reproductive[2]	Longevity[2]	Generation
$\bar{X}$[1]	25.02[a]	27.1[a]	30.9[a]	30.7[a]	20.4[a]	74.2[b]	201.6[c]	135.7[d]
S.D.	1.62	3.02	5.32	7.41	16.2	22.6	24.0	20.9
Range								
Hi	24.2	32.7	39.9	45.6	45.6	104.4	218.3	179.4
Low	20.1	23.4	24.9	24.6	9.3	41.1	167.4	119.1

[1]Means followed by the same letter are not significantly ($P \leq 0.05$) different, Duncan's new multiple range test.
[2]Data from 29.4°C deleted.

Significant regressions ($P \leq 0.05$) between temperature and adult reproductive period, and between temperature and longevity were found for the WA isolate (Table 2). When developmental data from 29.4°C were removed from this analysis no significant ($P \leq 0.05$) regressions for WA adult reproduction period ($Y = 102 - 1.8\times$, $R^2 = 3.7$) or longevity ($Y = 208 - 2.51\times$, $R^2 = 3.1$) were found. These results indicate that WA reproductive adults require more DD to develop at the upper extreme temperature. High relative humidity (80±20%) at 29.4°C may contribute to this difference since the WA isolate originated in the arid potato growing region of the Northwest.

No significant ($P \leq 0.05$) regressions (Table 2) between temperature and adult reproductive period and longevity for PA or ME isolates were found. The WA isolate was not considered different from PA or ME (29.4°C removed) because the isolates' pooled response across temperature (Table 2) was not significant ($P \leq 0.05$). The overall means calculated for all isolates (29.4°C removed) per adult reproductive period, longevity, and generation time were different ($P \leq 0.05$) (Table 3); 74.2, 201.6 and 135.7, respectively.

GPA biotypes utilized in this study required similar DD for development despite divergent geographical origin, clime, and originating host plant variety. The WA isolate demonstrated the only significant deviation and this occurred at the upper temperature extreme (29.4°C). The immature stages of the isolates required similar DD to complete development, yet generation time was a less variable estimate of the development from birth to production of first offspring and was the life stage parameter utilized to develop a field population prediction model for GPA (18). It may be concluded that thermal requirements for development of GPA infesting potatoes in Pennsylvania, Maine and Washington are similar except at temperatures near the upper developmental threshold (29.4°C).

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