RICE STINK BUG[1] DEVELOPMENT RELATIVE TO TEMPERATURE

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ABSTRACT

The rice stink bug, *Oebalus pugnax* (F.), is an important pest of rice, *Oryza sativa* L., in the United States. Little is known about the effects of temperature on its developmental rate. An experiment was conducted in temperature-controlled chambers to determine the effect of four constant temperatures on development of rice stink bug from egg to adult and to develop a degree-day model. The base of the rice panicle was immersed into a vial of water to provide food for nymphs and adults. The number of days required for egg hatch and the duration of each instar was recorded until adult eclosion. Developmental time of each instar differed significantly among temperatures. Egg hatch occurred at all temperatures except 15°C. At 15°C, second-instar development was monitored for 27 d but discontinued when food panicles became unavailable. Total development time from egg to adult was 36.8 d at 21°C, 31.6 d at 23°C and 17.9 d at 29°C. The lower developmental threshold varied from 12.1°C (third instar) to 14.7°C (second instar). The total degree-days accumulated above the average lower developmental threshold of 14°C from egg laying to adult eclosion were 281.1, 280.8 and 249.4 at 21, 23 and 29°C, respectively.

INTRODUCTION

The rice stink bug (RSB), *Oebalus pugnax* (F.) (Hemiptera: Pentatomidae), feeds on developing seeds of gramineous plants in the southern United States. The host range of RSB includes cultivated crops such as rice, *Oryza sativa* L.; barley, *Hordeum vulgare* L.; rye, *Secale cereale* L.; oats, *Avena sativa* L.; corn, *Zea mays* L.; sorghum, *Sorghum vulgare* Pers.; and wheat, *Triticum aestivum* L. (Odglen and Warren 1962). In Arkansas, from mid-April to early May, RSB emerge from overwintering sites, mostly woodland trash and bunch grass, (Odglen and Warren 1962). A rapid increase in RSB population has been noted with sweep net samples in rice during the grain-filling period and attributed to adult migration and egg hatch (Jones and Cherry 1986). Direct monitoring of RSB can be made using a sweep net, but patchiness of weed hosts often makes locating weed hosts tedious. The eggs are laid in two parallel rows and may be deposited on stems, leaves or panicles of different grasses (Nilakhe 1976). Freshly laid eggs are green and become red prior to hatching. The incubation is four to eight days, depending on temperature (Odglen and Warren 1962).

Under natural conditions, temperature largely determines the rate of development in insects (Liu et al. 1995). Several computational procedures exist for calculating daily degree-days and the practical application of predictive degree-day models (Pruess 1983, Higley et. al. 1986). The degree-day approach has been successfully applied for sucking insect pests, such as lygus bugs (Sevacherian et. al. 1977). No information is available for

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RSB in regards to temperature effects on developmental rate or a predictive degree-day program. This experiment was conducted to estimate a lower developmental threshold and degree-days accumulations for the development of RSB.

MATERIALS AND METHODS

In 2002, the duration of RSB development from egg to adult was determined in environmental chambers equipped with white 20-watt fluorescent lamps (Powers Scientific Inc., Hatboro, Pa; Model: DS33SD) maintained at 14:10 L:D photoperiod. The chamber temperatures were 15±1, 21±2, 23±2 and 29±2°C, respectively. Temperatures were recorded every 30 min using a StowAway™ Data Logger. RSB eggs were obtained from a laboratory caged colony. Adults were collected from rice fields and grass hosts at Stuttgart, AR, and maintained at the University of Arkansas Agricultural Experiment Station, Fayetteville at 28±2°C, 14:10 L:D photoperiod. The food was provided as greenhouse-grown, excised developing barnyardgrass, *Echinochloa crusgalli* (L.) Beauv., and rice, *Oryza sativa* L. panicles in milky stage with panicle bases immersed in 0.5-liter glass bottles half filled with water and secured with paper towels. The cages consisted of 19-liter plastic pails covered with 64-mesh nylon cloth. Cages were checked at 0800, 1300, and 1800 hours CDT for freshly laid cohorts of eggs. Eggs collected only at 1300 and 1800 hours CDT were used in this experiment. Cohorts of 30 eggs were incubated at each temperature in petri dishes containing a piece of moistened cotton (three replicates). In 1987, newly laid egg masses were removed daily from caged colonies (as above) (J. L. B., unpublished data). Seven to 20 egg masses of RSB were incubated in environmental chambers (Calumet Scientific Inc., Calumet, IL) set at 21.1±2°, 23.9±2°, 26.7±2°, 29.4±2°, 32.2±2°, 35.0±2° and 37.8±°C, respectively. Total hours to hatch were recorded for 90% of the eggs in a mass to hatch at each temperature. Total days to hatch were recorded for each egg. After hatch, first instars were provided with water-moistened cotton until molting into second instars.

Food was provided to nymphs for development rate studies. Typically, many pentatomids do not feed during the first instar (McPherson and McPherson 2000). Developing rice panicles were excised from the plants grown in the greenhouse. Panicles were cut in small pieces each with six to eight kernels in the milk or soft dough stage. Eppendorf® pipette tips were cut and modified to prepare a water-containing vase for the rice panicles. The base of each piece of rice panicle was inserted into the tip filled with water and secured with cotton. This feeding apparatus was placed in a 30–ml clear plastic diet cup (Solo Cup Co., Urbana, IL). Fifteen nymphs, newly molted to second instar, were randomly selected for each replication and placed at each temperature. A second-instar nymph was introduced onto the rice kernels in each diet cup with a camel's hair brush. The rice panicles were replaced every other day at 23±2 and 29±2°C, and after every two days at 15±1 and 21±2°C. Cups were examined twice daily at 0800–0900 and 1600–1700 hours CDT for mortality or cast exuviae until adults eclosed. The duration of each nymphal instar and sex of adult were recorded.

Daily degree-days were calculated by x-intercept method (Arnold 1959) and accumulated over days. The following degree-day formula was used:

$$\text{Degree-days} = \frac{\text{Daily Max. Temp.} + \text{Daily Min. Temp.}}{2} - \text{Lower Dev. Threshold}$$

Data on the effect of temperature on development time for each sex were analyzed with analysis of variance (ANOVA) and student's t-test to separate means (P=0.05). The stage-specific and overall lower developmental thresholds were determined by simple linear

TABLE 1. Mean Duration (Days ± SE) for Development and Percent Mortality of Eggs and Nymphs of the Rice Stink Bug, *Oebalus pugnax* (F.), at Different Temperatures.

Temp. (°C)	Stages (Egg or Instar): Egg	1	2	3	4	5	All
			Duration (days)				
15	-[a]	-	16.8 ± 0.54a[b]	17.0 ± 0.52a	-[c]	-	-
21	7.3 ± 0.07a	4.0 ± 0.04a	5.6 ± 0.21b	5.4±0.17b	5.9 ± 0.11a	8.7 ± 0.14a	36.8±0.32a
23	6.7 ± 0.07b	3.3 ± 0.07b	4.1 ± 0.13c	4.9 ± 0.20c	5.3 ± 0.13b	7.4 ± 0.13b	31.6±0.36b
29	4.3 ± 0.07c	2.0 ± 0.04c	2.0 ± 0.12d	2.3 ± 0.09d	3.1 ± 0.10c	4.2 ± 0.09c	17.9±0.20c
			Percent Mortality				
15	-	-	28.9	18.8	-	-	-
21	16.7	8.9	0.0	4.9	2.6	7.9	-
23	33.5	6.7	7.1	7.7	5.6	2.9	-
29	13.3	11.1	5.0	2.6	0.0	2.7	-

[a]Not hatched after being observed for 28 days.
[b]Means in same column with different letters are significantly different (P<0.05, Student's t test).
[c]Terminated due to unavailability of rice panicles.

regression of mean proportional growth (1/d, where, d = days for development) by temperature for the egg and each nymphal instar and across all stages (SAS Institute 1996).

RESULTS AND DISCUSSION

The duration of the period from oviposition to hatch became significantly shorter with increase in temperature (Table 1). No egg hatch occurred at 15±2°C although eggs were monitored for 28 d. There was no significant difference in development time between males and females at different temperatures ($P > 0.05$, Student's t test). The average duration from egg to adult at 29±2°C was 17.9 d compared to 31.6 and 36.8 d at 23±2 and 21±2°C, respectively (Table 1). Because no egg hatch was observed at 15±1°C, the experiment was initiated with second-instar nymphs from eggs incubated at 28±2°C. From the 1987 egg development experiment, total days to hatch were 11.2, 7.4, 5.5, 4.3, 3.8, 3.0 and 0 at 21.1±2, 23.9±2, 26.7±2, 29.4±2, 32.2±2, 35.0±2 and 37.8±2°C, respectively. Since no egg hatch occurred at 37.8°C, the upper developmental threshold for egg hatch was estimated between 35 and 37.8°C. At 15±1°C, the second instar required an average of 16.8 d. Third-instar nymphs were still feeding after 17 d, but the experiment was terminated due to unavailability of rice panicles. Percentage survival from egg to adult was 77.8, 73.3 and 80% at 21±2, 23±2 and 29±2°C, respectively.

The linear equations relating proportional growth to temperature for each stage are presented in Table 2. The lower developmental thresholds were 15.9, 13.2, 14.7, 12.1, 13.6 and 14.1°C for egg, and first to fifth instars, respectively. The average threshold across all stages was 14°C. Degree-days were calculated using this average lower developmental threshold (Table 2). The total degree-days accumulated from oviposition to adult eclosion were 281.1, 280.8 and 249.4 at 21, 23 and 29°C, respectively (Table 3). No developmental maximum was estimated for the other RSB stages. These findings need to be validated in the field.

TABLE 2. Linear Regression Equations of Mean Proportional Growth (Y) by Temperature (T) for Eggs and each instar of the Rice Stink Bug, *Oebalus pugnax* (F.).

Egg/Instar	Linear Equation	R^2	LDT[a] (°C)
Egg[b]	$Y = 0.017\,T - 0.27$	0.99	15.9
1st	$Y = 0.032\,T - 0.42$	0.99	13.2
2nd	$Y = 0.038\,T - 0.56$	0.90	14.7
3rd	$Y = 0.024\,T - 0.29$	0.86	12.1
4th	$Y = 0.022\,T - 0.30$	0.96	13.6
5th	$Y = 0.016\,T - 0.23$	0.99	14.1

[a]Lower developmental threshold.
[b]Egg development (J. L. B., unpublished data).

Given a biofix of first egg hatch, this degree-day information may be used to assist growers in predicting the earliest date when the first RSB nymphs will eclose to adults. At that time growers could begin scouting grass hosts in rice field margins for RSB presence and make decisions about their management. This information could be used to alert farmers with fields in heading, milk and dough (vulnerable stages) which coincide with adult eclosion. Similar control strategies based on degree-day models have been suggested for other hemipterans, such as, *Biprorulus bibax* (Breddin) (Pentatomidae), a major pest of citrus in Australia (James 1990) and *Calocoris norvegicus* (Gmelin) (Miridae), an important pest of pistachios in California (Purcell and Welter 1990).

TABLE 3. Cumulative Degree-Days (Lower Developmental Threshold = 14°C) for Eggs and Nymphs of Rice Stink Bug, *Oebalus pugnax* (F.), at Different Temperatures.

Temp. (°C)	Egg	Nymphal Stage					Total
		1	2	3	4	5	
21	55.3 (52.05 – 61.6)[a]	29.2 (29.1 – 29.3)	42.4 (39.7 – 43.7)	42.1 (39.8 – 43.2)	50.1 (49.8 – 50.8)	62.0 (56.3 – 65.2)	281.1 (274.2 – 290.4)
23	59.7 (56.2 – 66.54)	28.1 (18.6 – 37.4)	40.7 (37.6 – 47.0)	37.5 (37.4 – 37.6)	49.1 (34.4 – 56.4)	65.7 (56.4 – 75.0)	280.8 (259.6 – 291.5)
29	50.2 (46.9 – 52.7)	25.2 (22.1 – 28.0)	36.2 (30.6 – 39.2)	27.7 (22.1 – 30.6)	43.5 (38.8 – 45.8)	66.6 (61.1 – 77.5)	249.4 (237.9 – 259.3)

[a]Range in parentheses.

The degree-day model could improve the timing of releases of the egg parasitoid of RSB, *Telenomus podisi* (Ashmead). This parasitoid was found to parasitize up to 71% RSB eggs in the field (Sudarsono 1989). Mass releases of this parasitoid could be based on cumulative degree-days predicting the RSB oviposition period. This strategy may enhance the potential of the parasitoid as a biological control agent.

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LITERATURE CITED

Arnold, C. Y. 1959. The determination and significance of the base temperature in a linear heat unit system. *In* Proceedings of the American Soc. of Hort. Sci. 74: 430-445.

Bernhardt, J. L. 2000. Stink bugs: Control can pay off in higher yield, quality. Rice Journal. 130: 14-15.

Higley, L. G., L. P. Pedigo, and K. R. Ostlie. 1986. DEGDAY: A program for calculating degree-days, and assumptions behind the degree-day approach. Environ. Entomol. 15: 999-1016.

James, D. G. 1990. Development and survivorship of *Biprorulus bibax* (Hemiptera: Pentatomidae) under a range of constant temperatures. Environ. Entomol. 19: 874-877.

Jones, D. B., and R. H. Cherry. 1986. Species composition and seasonal abundance of stink bugs (Heteroptera: Pentatomidae) in southern Florida rice. J. Econ. Entomol. 79: 1226-1229.

Liu, S. S., G. M. Zhang, and J. Zhu. 1995. Influence of the temperature variations on rate of development in insects: Analysis of case studies from entomological literature. Ann. Entomol. Soc. Amer. 88: 107-119.

McPherson, J. E., and R. M. McPherson. 2000. Stink Bugs of Economic Importance in America North of Mexico. CRC Press LLC, N. W. Corporate Blvd., Boca Raton, Florida. 253 pp.

Naresh, J. S., and C. M. Smith. 1983. Development and survival of rice stink bugs (Hemiptera: Pentatomidae) reared on different host plants at four temperatures. Environ. Entomol. 12: 1496-1499.

Nilakhe, S. S. 1976. Overwintering, survival, fecundity and mating behavior of the rice stink bug. Ann. Entomol. Soc. Am. 69: 717-720.

Odglen, G. E., and L. O. Warren. 1962. The Rice Stink Bug *Oebalus pugnax* (F.) pp. 23. Ark. Agric. Exp. Stn., Univ. of Arkansas Rpt. Series 107.

Pruess, K. P. 1983. Day-degree methods for pest management. Environ. Entomol. 12: 613-619.

Purcell, M., and S. C. Welter. 1990. Degree-day model for development of *Calocoris norvegicus* (Hemiptera: Miridae) and timing of management strategies. Environ. Entomol. 19: 848-853.

SAS Institute. 1996. JMP Start Statistics: A Guide to Statistics and Data Analysis, Version 3.2.1. SAS Institute, Cary, NC.

Sevacherian, V., V. M. Stern, and A. J. Mueller. 1977. Heat accumulation for timing *Lygus* control measures in safflower-cotton complex. J. Econ. Entomol. 70: 399-402.

Simmons, A. M., and K. V. Yeargan. 1988. Development and survivorship of the green stink bug, *Acrosternum hilare* (Hemiptera: Pentatomidae) on soybean. Environ Entomol. 17: 527-532.

Sudarsono, H. 1989. *Telenomus podisi* Ashmead (Hymenoptera: Scelionidae): Seasonal Incidence in Succession of Rice Stink Bug Habitats and Mortality Rate in Rice following Applications of Methyl Parathion and Carbaryl. M.S. Thesis. Univ. of Ark., Fayetteville. pp. 68.