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The Effect of Temperature On the Life Cycle of The Alfalfa Seed Chalcid And Its Parasites

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CONTENTS

The Effect of Temperature On the Life Cycle of The Alfalfa Seed Chalcid And Its Parasites

By

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The life history of the alfalfa seed chalcid, *Bruchophagus roddi* Gussakovskii, has been reported from field studies by Urbahns (1920) and Sorenson (1934) and from laboratory studies by Strong (1962). Detailed studies of a number of its parasites have been reported by Urbahns (1916, 1917, 1919). Butler and Hansen (1958) listed the known parasites, with a key to species prepared by B. D. Burks. The host is listed by Urbahns as the alfalfa seed chalcis-fly, *Bruchophagus funebris* Howard, and by Sorenson, and by Butler and Hansen as the clover seed chalcid, *Bruchophagus gibbus* (Boheman). Urbahns (1919, 1920) lists one of the parasites, *Amblymerus bruchophagi,* in the genus *Eutelus,* as it was originally described.

The key to the alfalfa seed chalcid and its parasites by Burks in Butler and Hansen (1958) separates all of the known species of parasites, including several that are rare. *Liodontomerus longfellowi* (Girault) is apparently a parasite of the clover seed chalcid, *Bruchophagus gibbus,* and should be removed from the list. This is the parasitic species reported by Urbahns (1919, 1920) as *Liodontomerus secundus.* A simplified key to the alfalfa seed chalcid and the parasites most frequently encountered in western United States is given in the Appendix. Burks' key should be consulted for the identification of any odd specimens encountered.

This study was undertaken to determine the rate of development of the alfalfa seed chalcid and its parasites, as affected by temperature.

Methods

Regulated temperature cabinets were constructed by installing thermoswitches, heating coils, fans, and fluorescent lights in 311.3 dm^3 refrigerators. The lights were set to go on at 6 a.m. for a 15-hr. period. Three 45.7 cm fluorescent white

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bulbs, and a Gro-Lux[R] bulb, permitted good growth and flowering. The thermoswitches maintained the temperature to ± 1.5°C. Some of the cabinets were set at constant temperatures, but others were programmed for a diurnal fluctuation. In 1964, four cabinets were set at temperatures from 12.8 to 29.4°C, at 6° intervals, during the period from 6:00 p.m. to 6:00 a.m., then 11.1° higher from 6:00 a.m. to 6:00 p.m. In 1965, three cabinets were set to maintain temperatures of 10, 15, and 20°C, from 6:00 p.m. to 6:00 a.m., then 15°C higher from 6:00 a.m. to 6:00 p.m.

The alfalfa plants were grown in 15 cm clay pots in a greenhouse. When the flowers were to be pollinated, the plants were placed for several hours in a large cage with a colony of honey bees. Then a small plastic cage, similar to those used by Strong (1962), was placed over each raceme. After about 15 days, ten female *Bruchophagus* were placed in each cage for 24 hours and the plants transferred to temperature cabinets. If parasites were to be studied, the plants were held in the greenhouse for 7 to 9 days after being infestd by *Bruchophagus*. The plants were transferred to regulated temperature cabinets, 5 female parasites put in each cage for 24 hours, and the seeds dissected within a day or two. The full-grown *Bruchophagus* larvae were transferred to small holes in beeswax in the bottom of a 50 x 12 mm box-type petri dish and the dishes either returned to the controlled temperature cabinets or moved to a screen cage or greenhouse. These larvae were examined daily and the developmental stages of *Bruchophagus* and the parasites recorded according to Strong's (1962:239) arbitrary numbers.

Alfalfa pods with chalcid-infested seeds also were placed in 9 cm petri dishes and one or more adult parasites introduced. The parasites readily oviposited in the pods, which could be opened immediately to obtain the parasitized chalcid larva for daily observation.

During 1958, seed samples were obtained from more than 190 alfalfa fields in Arizona, California, Idaho, Utah, and Washington. Additional samples were obtained from Utah in 1960, New Mexico in 1961, and Arizona and Washington in 1964. Each sample of alfalfa seed was placed in a gallon ice-cream container and the adult alfalfa seed chalcids and parasites allowed to emerge. The percentage of the various species of parasites present was determined from these samples.

Results

Bruchophagus roddi Guss.

To determine the duration of the various stages of development, alfalfa seed chalcids were dissected from 287 field-collected alfalfa seeds in 1964, and from 1694 field-collected and laboratory-reared seeds in 1965. Many of the larvae went into diapause, others had been parasitized, and still others died. Detailed records of the development from egg to adult at different temperatures were made for 85 individuals in 1965. The average duration of the egg and larval stages combined, the pupal stage, the egg through pupal stages combined, and the regression equations for each of these periods at fluctuating temperatures, are given in Table 1. The egg and larval stages combined varied from 12.8 to 21.5 days, the pupal stage from 5.1 days to 13.2, and the total period from the laying of the egg to the emergence of the adult from 18.1 to 34.3 days, at 29.4°C and 18.3°C, respectively.

TABLE 1. The mean duration in days of the egg and larval stages, pupal stage, and egg to adult period of *Bruchophagus roddi* at different temperatures.

Temperature C		Egg & Larval		Pupal		Egg to Adult	
		No. Individ.	Mean	No. Individ.	Mean	No. Individ.	Mean
19.4	(10.0 to 25.0)	8	20.4	77	11.1	8	31.1
24.4	(15.0 to 30.0)	13	15.4	119	7.4	17	22.8
24.4	greenhouse	18	14.4	19	6.4	19	20.8
25.0	constant	—	—	31	5.7	—	—
26.1	greenhouse	—	—	9	5.8	—	—
28.3	(20.0 to 35.0)	32	13.5	122	5.3	32	18.8
28.3	outside cage	9	13.3	10	5.0	9	20.1
30.0	constant	—	—	34	4.3	—	—
31.7	outside cage	—	—	16	5.1	—	—
35.0	constant	—	—	9	3.6	—	—
$\hat{y} = a + bX$ [a]		$\hat{y} = -.00536 + .00283X$		$\hat{y} = -.126 + .0110X$		$\hat{y} = -.0140 + .00236X$	
R^2		.99		.98		.99	

[a] Regression equation $\hat{y} = a + bX$ where $\hat{y}$ is the reciprocal of the number of days at 3 fluctuating temperatures and X is the temperature.

Additional records were obtained for the late larval and pupal stages in 1964, 1965, and 1966. A summary of these records is given in Table 2. The developmental stages are designated according to Strong (1962). Stage 11 (all-black pupa) and stage 8 (white-eyed pupa) took the longest, varying from 1 to 6 days, depending on the temperature.

The Parasites

The life cycles of the different species of parasites of the alfalfa seed chalcid included in this study follow a very uniform pattern. Sorenson (1930: 28) described the development as follows:

> "Female parasites insert their eggs into soft alfalfa seeds containing larvae or occasionally pupae of the chalcis-fly. One egg only is ordinarily inserted into an infested alfalfa seed. Upon hatching from the eggs, the young parasitic larvae begin feeding upon the larvae of the seed chalcid. Feeding proceeds until the entire body of the host, excepting its jaws, is devoured by the parasite. After feeding has been completed, the parasitic larva may pupate and transform within a few days into the adult stage, or they may hibernate and pass through the winter as larvae to pupate and transform during the following spring or summer. The time of pupation

TABLE 2. The mean duration in days of the developmental stages of *Bruchophagus roddi* at different temperatures.

Temperature C		Stage of Development												Duration of stage
		Mature larva defecated		Prepupa		Pupal Eye Color						Black Pupa		
						white		pink		brown				
		No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	
18.3	(12.8 to 23.9)	16	0.9	16	1.5	16	5.8	16	2.8	16	1.1	16	5.1	14.8
19.4	(10.0 to 25.0)	65	0.9	74	1.3	79	3.9	84	2.6	84	0.8	84	5.7	11.1
20.0	constant	—	—	—	—	81	4.4	81	2.4	81	1.0	81	3.9	11.7
23.9	constant	13	1.3	13	0.9	13	2.8	13	1.8	13	0.5	13	3.1	8.2
23.9	(18.3 to 29.4)	—	—	15	1.0	15	2.8	15	1.8	15	0.5	15	2.9	8.0
24.4	(15.0 to 30.0)	92	0.7	101	0.9	111	2.0	124	1.7	128	0.6	128	2.4	7.4
25.0	constant	—	—	—	—	61	2.4	61	1.3	61	0.6	61	2.5	6.8
25.0	constant	21	0.4	25	0.6	32	2.1	34	1.2	34	0.5	33	2.9	5.7
27.2	constant	—	—	—	—	58	1.9	58	1.2	58	0.5	58	1.9	5.4
28.3	(20.0 to 35.0)	96	0.6	103	0.5	118	1.8	129	1.2	129	0.5	129	1.8	5.3
29.4	(23.9 to 35.0)	14	1.3	14	0.7	14	1.8	14	0.9	14	0.5	14	1.9	5.1
30.0	constant	—	—	—	—	95	1.4	95	1.0	95	0.4	95	1.3	4.2
30.0	constant	23	0.3	26	0.4	34	1.5	34	0.9	34	0.5	34	1.3	4.3
35.0	(29.4 to 40.5)	21	0.8	21	0.7	21	1.4	21	1.0	21	0.4	21	1.7	4.1
35.0	constant	—	—	6	0.8	10	1.0	10	0.9	10	0.2	10	1.4	3.6

and transformation, whether it follows shortly after feeding has been completed or whether it occurs during the next spring or summer, seems to be determined by certain temperature and moisture relationships. Pupation and transformation takes place inside of the seedcoat and the newly transformed adult parasite gnaws a hole in the seedcoat and in the pod through which it escapes."

The distribution, hosts, and life cycle in relation to temperature for each of the alfalfa seed chalcid parasites arranged in alphabetical order follow:

Amblymerus bruchophagi (Gahan)

This parasite is of economic importance only in the mountain valleys of southern Idaho and central Utah, according to Urbahns (1920). It also is recorded from New York, Wyoming, Idaho, and northern California, but was not found in the southwestern alfalfa seed-growing districts. According to Peck (1963), the hosts are *Bruchophagus caraganae* Nikolskaja, *B. gibbus, B. kolobovae* Fedoseeva, *B. mexicanus* Ashmead, and *B. roddi.*

The eggs of *A. bruchophagi* were laid externally on the host and the larvae fed externally. The egg stage varied from 1 to 2 days, while both the larval and pupal stages varied from approximately 4 to 8 days, as shown in Table 3. The regression equation for the time required for the egg through the adult stage at temperatures between 20° and 30°C is $\hat{y} = -.0736 + .00641X$ ($R^2 = .98$), where $\hat{y}$ is the reciprocal of the duration in days and X is the temperature.

Habrocytus medicaginis Gahan

This species is widely distributed throughout the United States but is not abundant in most areas. It is sometimes the dominant parasite in Utah and may be important in Washington. Although Yuma, Arizona, is the type locality for this species, it has not been recovered from our samples. The hosts are *B. gibbus, kolobovae,* and *roddi,* according to Peck (1963).

Urbahns (1916) observed that *H. medicaginis* was parasitic upon the larval stage of its host, with possibly a few exceptions. In no case was it found to attack the pupa of *B. roddi.* In our studies, adult *H. medicaginis* were placed in covered petri dishes for 24 hours with alfalfa pods from the field that were infested with *B. roddi.* The alfalfa seeds were dissected after the adults were removed and chalcid larvae examined for *H. medicaginis* eggs. A number of stage

TABLE 3. The mean duration in days of the stages of *Amblymerus bruchophagi* at different temperatures.

Temperature	Egg		Larva		Pupa		Egg to Adult	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
20.0	2	2.0	2	7.5	2	8.5	2	18.0
25.0	15	1.3	12	5.8	12	5.0	9	12.0
27.2	9	1.3	9	4.3	9	4.2	9	9.7
30.0	8	1.0	16	4.8	16	4.1	8	9.8

TABLE 4. The mean duration in days of the stages of *Habrocytus medicaginis* at different temperatures.

Temperature	No.	Egg and larva	Pupa	Egg to adult
18.9 (10.0 to 25.0)	10	10.6	8.7	18.8
25.0 (15.0 to 30.0)	10	8.2	6.6	15.1
28.9 (20.0 to 35.0)	8	6.9	5.5	12.5
35.0 constant	7	5.9	4.1	9.4

7 prepupae and a few stage 8 pupae were parasitized, but most of the parasitized *B. roddi* were in the larval stage.

The eggs of *H. medicaginis* are laid externally on the host and the larva feeds externally. Urbahns (1916) observed that the newly hatched larva may move about on the host for several hours before it begins to feed. It then may completely destroy its host and become fully developed within a minimum period of 5 or 6 days after taking its first food. He noted that the minimum duration of the larval stage was normally about 12 days and the maximum a year or more in the case of diapause.

The duration of the egg and larval stages is shown in Table 4, and varies from 10.6 days at 18.9°C to 5.9 days at 35.0°C. The regression equation for the time required for the egg through the larval stage at temperatures between 18.9° and 35.0°C is $\hat{y} = -.00516 + .00473X$ ($R^2 = .99$), where $\hat{y}$ is the reciprocal of the duration in days and X is the temperature.

The duration of the pupal stage is about 10 days under favorable field conditions in midsummer, according to Urbahns (1916). Under laboratory conditions at approximately out-of-door temperatures at Glendale and Pasadena, California, the duration of the pupal stage varied from 10 to 52 days, with the long periods in March and April. The *H. medicaginis* pupa is white when newly formed and goes through a series of color transformations similar to *B. roddi.* The detailed development of the prepupal and pupal stages at different temperatures during 1965 is given in Table 5. The duration of the pupal stage at different temperatures is given in Table 4. The regression equation for this stage between

TABLE 5. The mean duration in days of the developmental stages of *Habrocytus medicaginis* at different temperatures.

Temperature	No. of individ.	Mature Larva, Defecated	Prepupa	Pupal Eye Color: White	Pupal Eye Color: Pink	Pupal Eye Color: Brown	Black Pupa
18.9 (10.0 to 25.0)	10	0.3	1.0	2.1	3.7	0.7	2.2
25.0 (15.0 to 30.0)	14	0.2	0.7	1.2	2.9	0.6	1.9
28.9 (20.0 to 35.0)	7	<1	0.8	1.8	1.8	0.8	1.2
35.0 constant	7	—	—	0.9	0.7	0.7	1.0

18.9° and 35.0° is $\hat{y} = -.04032 + .00799X$ ($R^2 = .98$), where $\hat{y}$ is the reciprocal of the duration of the pupal stage in days and X is the temperature. The time from the egg to the adult stage was determined for 35 individuals at 4 temperatures. The regression equation for this period is $\hat{y} = -.0128 + .00331X$ ($R^2 = .97$), where $\hat{y}$ is the reciprocal of the duration of the period in days and X is the temperature.

Liodontomerus insuetus Gahan

This parasite has not been of economic importance, and in our samples was less than 1 percent of the parasites observed. It is found in California, Arizona, New Mexico, Kansas, and Oklahoma. The hosts are *B. kolobovae* and *B. roddi,* according to Peck (1963).

The eggs are laid externally on the host larva and require from 1 to 2 days to hatch, as shown in Table 6. The larval and pupal periods each varied from 4 to 6 days in duration at temperatures of 27.2 and 30.0°C.

Liodontomerus perplexus Gahan

L. perplexus is widely distributed and appears most active during mid-summer. In samples collected in 1958, it was by far the most abundant parasite of the alfalfa seed chalcid obtained in samples from Washington, California, Utah, and Arizona. In September, 1961, it accounted for approximately half of the parasitism in New Mexico. It is a parasite of both *B. gibbus* and *B. roddi,* according to Peck (1963).

Observations were made on oviposition activity of females held in the laboratory on field-collected alfalfa pods. The pods were at least 3 weeks old and were very dry. A female diligently searched over the pods while keeping the tips of her antennae on the surface. The antennae were constantly in motion and each antenna seemed to function independantly of the other. After the female had found a suitable host she very carefully ran her antennae over the surface of the pod directly over the infested seed, and placed her ovipositor onto the exact spot that had been so thoroughly examined. As the abdomen was bent downward, the sheath of the ovipositor was positioned beneath the metathorax and the tip was forced into the pod. The abdomen was then straightened out, leaving exposed the ovipositor, which was pushed through the tough pod and into the seed with movements of her body. The time required for oviposition was approximately 3 minutes.

Eggs of *L. perplexus* were found on mature larvae, larvae that had defecated,

TABLE 6. The mean duration in days of the stages of *Liodontomerus insuetus* at different temperatures.

Temperature	Egg		Larval		Pupal		Egg to Adult	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
27.2	10	1.4	4	5.8	4	6.0	4	13.2
30.0	3	1.7	3	4.7	3	4.2	3	10.7

white-eyed pupae, and a black pupa. In the last case, the *B. roddi* developed into an adult and left the seed before the parasite egg hatched. Some field-collected *B. roddi* larvae had as many as three *L. perplexus* eggs laid on them. *L. perplexus* larvae were also observed feeding on other parasitic species attacking *B. roddi.* In several cases, the *L. perplexus* egg did not hatch before an internal parasite, such as *T. bruchophagi,* had completed its feeding and emerged from the *B. roddi* larva. When the *L. perplexus* egg hatched, the larva then attacked the *T. bruchophagi* larva.

Eggs, laid on or very near the host larvae and pupae, were transparent and resembled an inflated plastic bag with a small hook on one end. Each of a series of 12 eggs measured 0.4 mm in length. The duration of the egg stage at different constant and fluctuating temperatures was determined and the results are shown in Table 7. The egg stage lasted from 1 to 3 days. It was shorter at constant than at comparable fluctuating temperatures. Upon hatching, the larva positioned itself on the body of the host larva and began to feed. It apparently punctured the epidermis of the host and sucked out the internal fluids. Gradually the body of the host shriveled and became black, while the parasite larva grew in size. The duration of the larval stage varied from approximately 12 days at 20°C to 5 days at 30°C, as shown in Table 7.

The duration of the pupal stage at different temperatures is also shown in Table 7 and varied from 11.6 days at 20°C to 4.1 days at 30°C.

Observations by Urbahns (1919) showed that under very favorable conditions, *L. perplexus* required about 30 days for the complete development of a single generation. Therefore he concluded that there may be as many as three generations in a single season in alfalfa seed fields of Arizona and southern California. The length of the life cycle of *L. perplexus* was determined in 1964 from eggs laid on mature *B. roddi* larvae that had not defecated. The development

TABLE 7. The mean duration in days of the stages of *Liodontomerus perplexus* at different constant and fluctuating temperatures.

Temperature	Egg		Larva		Pupa		Egg to Adult	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Constant								
20.0	18	2.8	21	12.3	31	11.6	11	26.5
25.0	20	2.0	39	7.5	70	6.4	17	16.4
27.2	18	1.4	26	5.8	32	5.6	15	12.9
30.0	16	1.1	25	5.1	45	4.1	14	9.9
Fluctuating								
19.4 (10.0 to 25.0)	—	—	2	16.0*	2	8.9	2	26.0
23.8 (18.3 to 29.4)	17	2.9	—	—	5	7.8	—	—
27.5 (20.0 to 35.0)	—	—	7	9.4*	7	4.9	7	14.4
29.4 (23.9 to 35.0)	23	2.4	—	—	21	5.8	21	14.6
35.0 (29.4 to 40.5)	7	2.0	—	—	2	5.0	—	—

* Egg plus larval stages.

TABLE 8. The average length in days of the life stages of 21 *Liodontomerus perplexus* maintained at an average temperature of 29.4°C while fluctuating between 23.9 and 35.0°C every 12 hours.

Stage	Duration in days Mean
Egg Stage	2.8
Larval Stage	3.5
Larva, mature, not defecated	1.5
Larve, mature, defecated	0.7
Prepupa	0.3
Pupa, eyes white	2.1
Pupa, eyes pink	1.7
Pupa, eyes brown	1.0
Pupa, all black	1.0
Total	14.6

of 21 eggs was observed daily in dishes held at an average temperature of 29.4°C but fluctuating between 23.9 to 35.0° every 12 hours. The results are summarized in Table 8. The egg stage averaged 2.8 days in duration, the larval stage 6.0 days, and the pupal stage 5.8 days. The total developmental time at an average temperature of 29.4°C was 14.6 days from egg to adult, approximately one-half of the time observed by Urbahns. This temperature was approximately 2.4 degrees below the monthly average temperature at Yuma, Arizona, during July and August.

The time from the egg to the appearance of the adult at different constant and fluctuating temperatures varied from 26.5 days at 20°C to approximately 10 days at 30°C, as shown in Table 7. The regression equation for the number of days for the development of *L. perplexus* from egg to adult from 20° to 30°C is $\hat{y} = -.0229 + .00317X$ ($R^2 = .98$), where $\hat{y}$ is the reciprocal of the number of days for development and X is the temperature. This rate of development is similar to that of *T. bruchophagi.*

Tetrastichus bruchophagi Gahan

This species is generally distributed throughout the United States. Samples from Arizona taken in 1958 contained various percentages, from 3 percent in seed collected at Yuma from September to December, to 80 percent from Yuma during January to May. In Arizona, *T. bruchophagi* was more abundant early in the season and less abundant during the summer, when *L. perplexus* was usually the dominant species. *Liodontomerus* populations did not develop to large numbers at Tucson during 1965, and *T. bruchophagi* remained the most abundant parasite throughout the summer. Urbahns (1917) considered it a species of little importance at Yuma, because it destroyed only about 1.5 percent of the *Bruchophagus* larvae.

Rearings in 1958 showed no *T. bruchophagi* in samples from Prosser, Washington; 9 percent of the parasites were this species in collections from Logan, Utah (14 percent in late August, 1960); less than 1 percent from Delta, Utah; none in 6 samples from Kern County, California; and 2 percent from 8 samples from Fresno County, California. Five samples taken in September, 1961, from New Mexico had 55 percent of the parasites of this species. Urbahns (1917) considered it of considerable importance in central California in 1913, when it apparently destroyed 52 percent of the *Bruchophagus* larvae.

This parasite is not restricted to the alfalfa seed chalcid. Peck (1963) lists the hosts as *B. gibbus, kolobovae* and *roddi;* the alfalfa weevil, *Hypera postica* (Gyllenhal) and its ichneumonid parasite, *Bathyplectis curculionis* (Thomson) and possibly the cecidomyiid fly of alfalfa, *Asphondylia websteri* Felt.

In studies during 1964, 1965, and 1966, *T. bruchophagi* developed as an internal parasite. The mature larva emerged from the posterior end of the *Bruchophagus* larva or prepupa, leaving behind a small, crumpled mass of host cuticle. Urbahns' (1917) findings were quite different. He reported that it is normally an external parasite, attaching itself to the half-grown to fully developed larva, puncturing the cuticle and feeding on the body contents. In several instances the larva was completely enclosed within the host larva.

The duration of the egg and larval stages varied from 10.2 days at 20.0°C to 4.9 days at 27.2°C, as shown in Table 9. There was a reduction in the rate of development of the egg and larval stage at 30.0°C. Urbahns (1917) reported that the larval stage did not require more than about 10 days under favorable conditions.

The developmental stages of *B. roddi* from which 55 *T. bruchophagi* emerged at different temperatures in 1964 are given in Table 10. The temperature did not affect the host stage from which the parasite emerged. The parasite generally emerged from a mature larva that had defecated, or from a prepupa. Similar results were obtained in 1965.

The pupa was white at first and then darkened to black in a series of changes similar to *B. roddi.* The duration of the various developmental stages from mature larva to adult for 229 *T. bruchophagi* at 13 temperatures is given in Table 11. The regression equation for the duration of the pupal stage (developmental stages 8 to 11) from 18.3° to 35.0°C is $\hat{y} = -.0602 + .00877X$ ($R^2 = .83$), where $\hat{y}$ is the reciprocal of the duration of the pupal stage in days and X is the temperature. The duration of the pupal stage varied from ap-

TABLE 9. The mean duration in days of the stages of *Tetrastichus bruchophagi* at different temperatures.

Temperature	Egg and larva		Pupa		Egg to Adult	
	No.	Mean	No.	Mean	No.	Mean
20.0	9	10.2	38	9.2	9	19.0
25.0	10	6.9	68	5.6	10	13.2
27.2	12	4.9	54	4.8	12	9.7
30.0	66	6.4	104	4.0	67	10.5

TABLE 10. The developmental stages of *Bruchophagus roddi* from which *Tetrastichus bruchophagi* emerged at different temperatures.

Temperature		Number of Individuals	Stage of Development* Mean Stage ± Standard Deviation	Range
18.3	(12.8 - 23.9)	15	6.8 ± .97	5 to 8
23.9	(18.3 - 29.4)	6	7.5 ± .5	7 to 8
29.4	(23.9 - 35.0)	10	6.3 ± .78	5 to 8
35.0	(29.4 - 40.5)	4	6.8 ± 1.1	5 to 8
23.9	Constant	17	6.8 ± 1.1	5 to 9
35.0	Constant	3	6.7 ± 0.5	6 to 7

* 6 = mature larva, white, has defecated; 7 = prepupa

TABLE 11. The mean duration in days of the developmental stages of *Tetrastichus bruchophagi* at different temperatures.

Temperature	No. of Individuals	6 Mature larva, defecated	7 Prepupa	8 Pupa, eyes white	9 Pupa, eyes pink	10 Pupa, eyes brown	11 Pupa, all black	Duration of pupal stage
		Arbitrary number and stage of development						
18.3 (12.8 to 23.4)	16	1.2	0.6	1.2	6.5	1.5	2.4	11.7
19.4 (10.0 to 25.0)	23	0.6	1.1	2.3	4.3	1.0	2.1	9.8
23.9 (19.4 to 29.4)	6	0.7	0.5	1.8	3.0	1.0	1.5	7.3
23.9 (constant)	20	0.6	0.4	1.6	2.6	0.8	1.5	6.6
24.4 (15.0 to 30.0)	47	0.4	0.7	1.5	3.2	0.9	1.2	6.7
25.0 (constant)	13	0.3	0.4	1.1	2.3	0.5	1.1	5.0
28.3 (20.0 to 40.5)	40	0.4	0.5	1.2	2.6	0.8	1.0	5.6
28.9 (outside)	10	<1	0.3	1.2	2.7	0.4	1.6	5.9
29.4 (23.9 to 40.5)	12	0.6	0.4	1.0	2.3	0.5	1.0	4.8
30.0 (constant)	17	0.3	0.6	1.0	1.8	0.8	0.8	4.2
30.6 (outside)	8	<1	0.6	1.1	2.1	0.8	1.1	5.1
35.0 (constant)	9	<1	0.7	0.9	1.9	0.4	0.8	4.0
35.0 (constant)	8	0.6	0.4	0.9	2.0	0.4	0.6	3.9

TABLE 12. The mean duration in days of the stages of *Trimeromicrus maculatus* at different temperatures.

Temperature	Egg		Larva		Pupa		Egg to Adult	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
20.0	10	2.0	4	7.5	31	8.3	4	16.5
25.0	11	1.0	15	5.2	68	4.4	16	10.4
27.2	13	1.1	10	4.5	43	3.8	10	9.8
30.0	8	1.0	8	3.8	32	3.2	8	8.0

proximately 12 days at 18.3° to 4 days at 35.0°C, with a reduction in the rate of development at temperatures above 35.0°C.

The total time required from the egg to adult stage varied from 19.0 days at 20.0°C to 9.7 days at 27.2°C, as shown in Table 9. The regression equation for the duration of this development from 20.0 to 27.2°C is $\hat{y} = -.0813 + .00659X$ ($R^2 = .92$), where $\hat{y}$ is the reciprocal of the duration of the egg to adult period in days and X is the temperature.

Trimeromicrus maculatus Gahan

T. maculatus is found generally throughout the western United States. In 1958, samples from Washington had 20 percent of this species, Utah 2 to 3 percent, California 5 to 17 percent, and Arizona from less than 1 to 36 percent. The September 1961 samples from New Mexico had an average of less than 1 percent of this species. In 1954, *T. maculatus* began to emerge at Tucson in early March, before *T. bruchophagi,* and had completed its emergence by mid-April, when *L. perplexus* began to appear.

The hosts, as given by Peck (1963), are two curculionids, *Ceutorhynchus assimilis* (Paykull) and *Desmoris fulvus* (LeConte), the cecidomyiid fly on alfalfa, *A. websteri,* and *B. gibbus, kolobovae,* and *roddi.* In our observations the larval stage of *B roddi* was attacked and sometimes the prepupal stage. One case was observed where the egg was sloughed off with the prepupal skin but the hatching larva was still able to attack the host pupa.

The egg was laid externally on the *B. roddi* larva and lasted 1 to 2 days. The duration of the other stages at different temperatures is shown in Table 12. The egg to adult period varied from 16.5 days at 20.0°C to 8.0 days at 30.0°C. The regression equation for the time required for the egg to adult stage at temperatures between 20.0 and 30.0°C is $\hat{y} = -.0637 + .00625X$ ($R^2 = .98$), where $\hat{y}$ is the reciprocal of the duration in days and X is the temperature.

Conclusions

The rate of development of the alfalfa seed chalcid from egg to adult was much slower than that of any of its five principal parasites in the western United States. Of the parasites, *A. bruchophagi* and *T. bruchophagi* developed most rapidly, *L. perplexus* the most slowly.

Appendix

Key to Species

1. Body black, the head and thorax with coarse, flat-bottomed punctures. Prothorax transversely quadrate, distinctly set off from rest of thorax. Antennae simple, as in Figure 1 (♀), or with the flagellar segments quadrate and bearing long, erect setae (♂). F. Eurytomidae . . . . *Bruchophagus roddi*

   Body at least slightly metallic in most species. Punctures on head and prothorax not coarse and flat-bottomed, and prothorax not strongly set off from rest of thorax 2

2. Mesonotum with a median groove, scutellum with 4 parallel groves. Body dull green, with metallic reflections, the head and thorax without distinct punctures. Abdomen evenly tapered to tip, as in Figure 2, the apical segments split along the middle ventrally (♀), or more truncate, with a short median projection and the apical segments entire ventrally (♂). F. Eulophidae. Common in Arizona, occasional elsewhere . . . . *Tetrastichus bruchophagi*

   Mesonotum and scutellum without longitudinal grooves, the head and thorax distinctly punctured 3

3. Prothorax somewhat conical, tapering to attachment of head. Head and thorax metallic green, abdomen bronze. Female (Figure 4) with long ovipositor, the sheaths from ½ to ⅔ as long as abdomen, the apical segments of the abdomen divided on middle of underside; male with a short projection at apex of abdomen and apical segments not divided ventrally. F. Torymidae. Common in all areas. (A rare species, *L. insuetus* Gahan, has the ovipositor sheaths slightly longer than the abdomen in the female; the male is unknown) . . . *Liodontomerus perplexus*

   Prothorax short and transverse, not conical. Ovipositor of female not extending noticeably beyond apex of abdomen 4

4. Legs and antennae entirely yellow, the last segment dark; body shiny green. F. Pteromalidae. Sometimes common from Utah northward; does not range southward . . . . *Amblymerus bruchophagi* ♂

   Femora and antennae partly dark 5

5. Head and thorax distinctly blue-green. F. Pteromalidae. Sometimes common in Utah and Washington, very rare in Arizona. (Figure 5.) Male unknown . . . . *Habrocytus medicaginis* ♀

   Head and thorax faintly bronze to greenish black. F. Pteromalidae. Sometimes common from Utah northward; does not range southward. (Figure 3) . . . . *Amblymerus bruchophagi* ♀

   Head and thorax dull black, the thorax with 4 metallic spots across the front, sometimes obscure in ♂ , which has a small projection at the apex of the abdomen and the apical segments not medially divided ventrally. F. Pteromalidae. Sometimes moderately abundant in all areas. (Figure 6) . . . . *Trimeromicus maculatus*

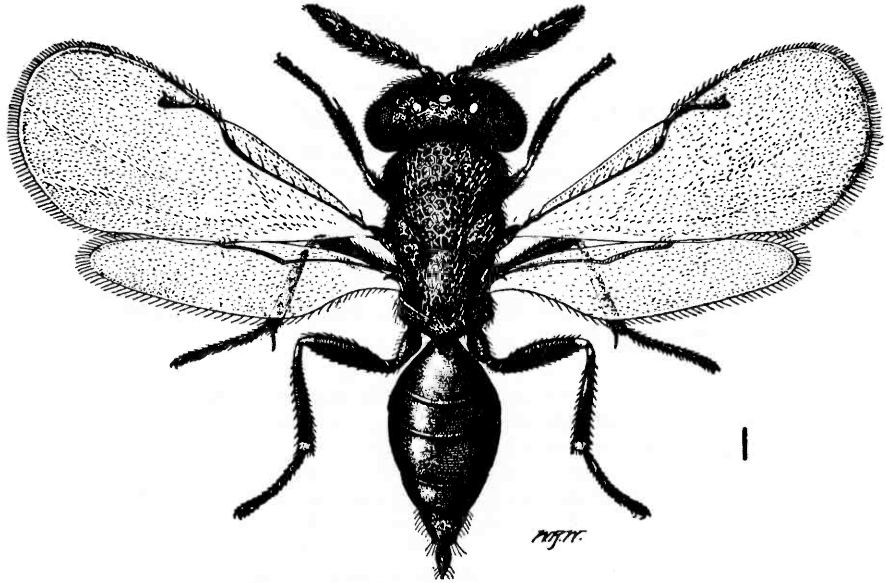

FIG. 1. — *Bruchophagus roddi* Gussakovskii, ♀.

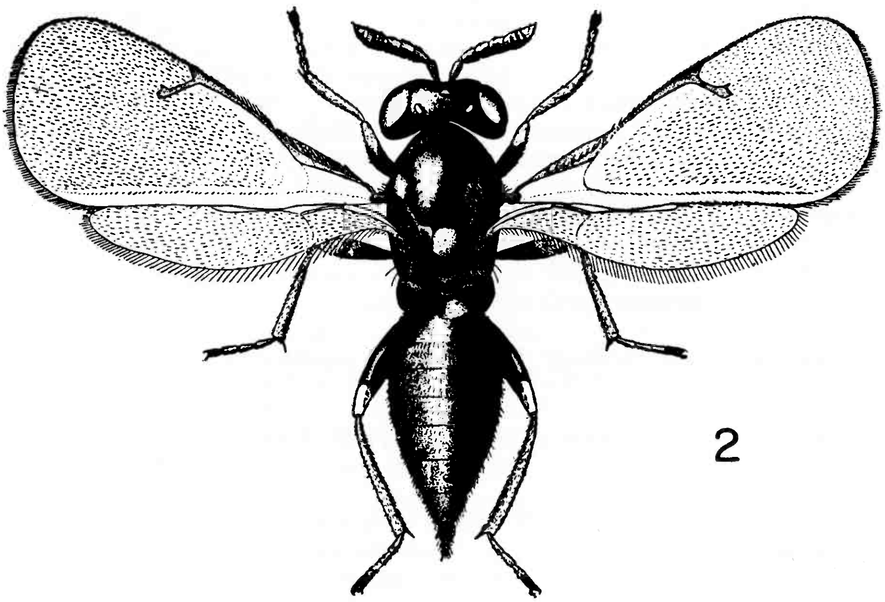

FIG. 2. — *Tetrastichus bruchophagi* Gahan, ♀.

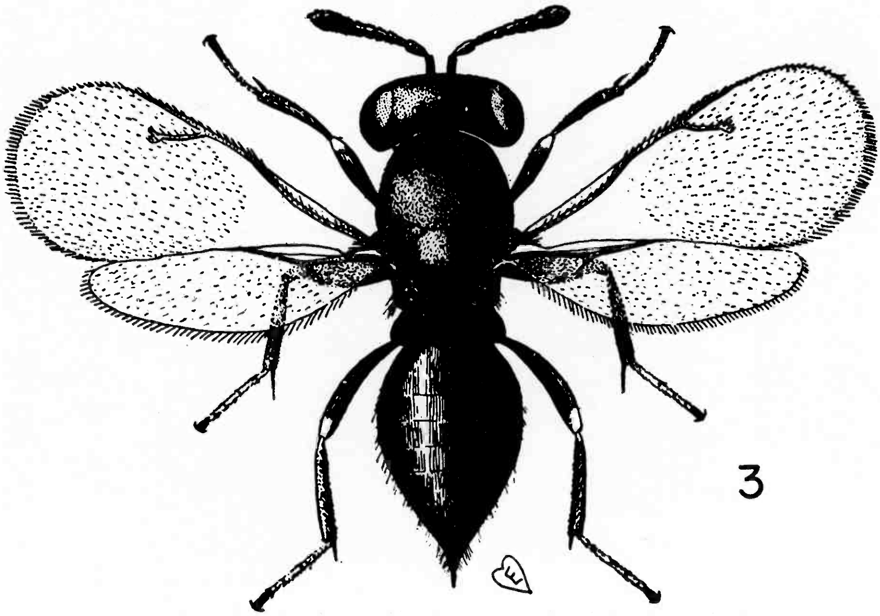

FIG. 3 — *Amblymerus bruchophagi* (Gahan), ♀.

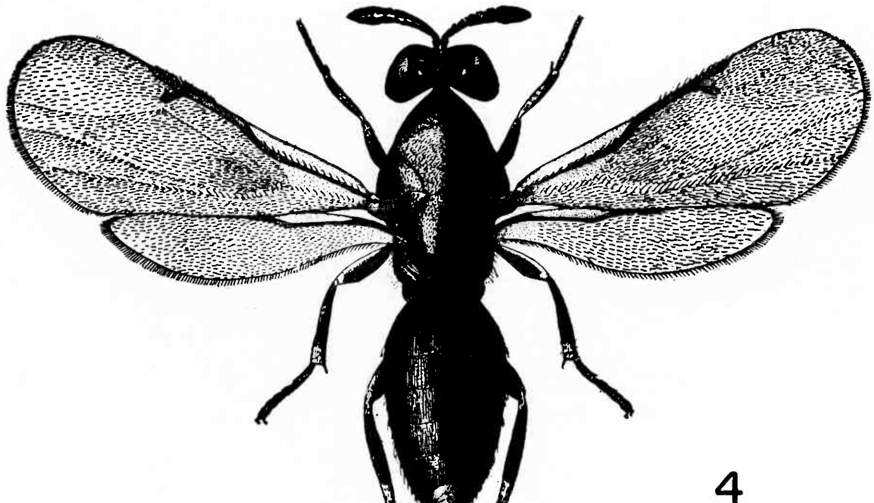

FIG. 4 — *Liodontomerus perplexus* Gahan, ♀.

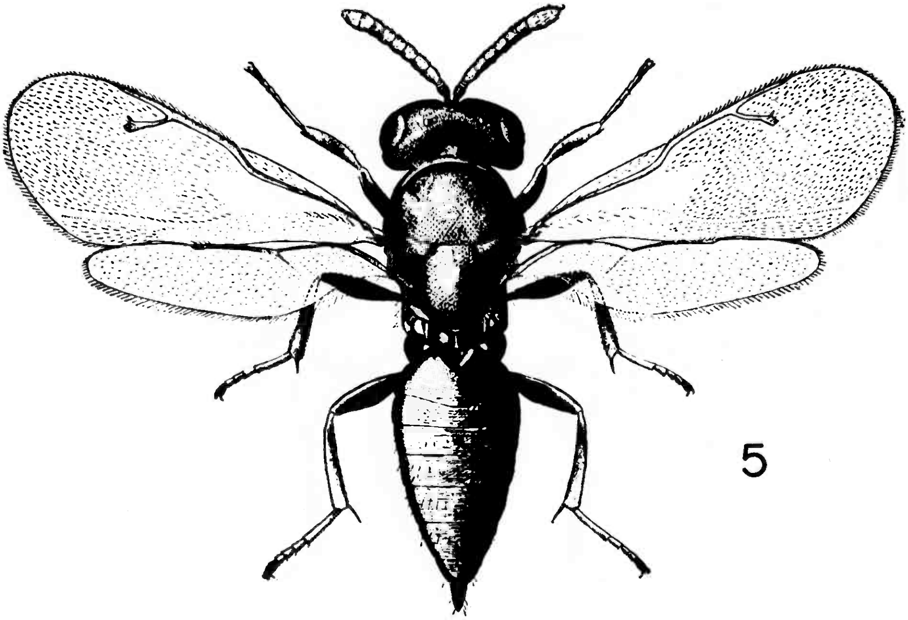

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FIG. 5 — *Habrocytus medicaginis* Gahan, ♀.

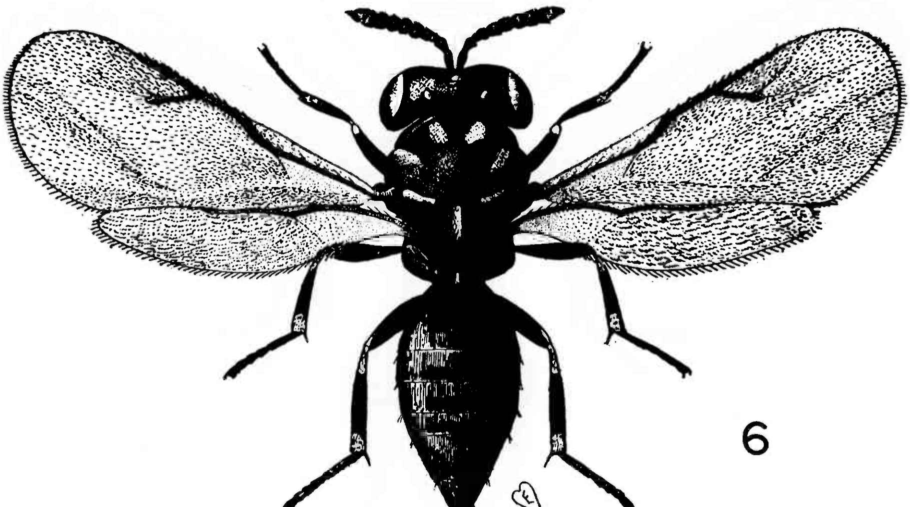

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FIG. 6. — *Trimeromicrus maculatus* Gahan, ♀.

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