THE EFFECT OF PARASITISM BY *LYSIPHLEBUS TESTACEIPES* (CRESSON) ON THE FECUNDITY OF THE SORGHUM GREENBUG, *SCHIZAPHIS GRAMINUM* (RONDANI)

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PREFACE

Sorghum has become increasingly important to the agricultural economy of the Great Plains during the past few years. This has necessitated the placing of greater emphasis on production problems, among which is the economical control of injurious pests. The severe outbreak of *Schizaphis graminum* on sorghums in 1968 caused considerable damage throughout the Great Plains, and possible avenues of control had to be considered.

Chemicals have been the main means of control; however, the recent banning of many insecticides has brought attention to the use of other types of control. Biological control, the action of parasites and predators, or pathogens in maintaining another organism's population density below the economic threshold, is being considered as an alternate to chemical spraying. Observations by early workers in biological control showed that certain insects were valuable agents in limiting the population numbers of their hosts. Some success has been attained in biological control by several states (ie. California, Indiana, Missouri, etc.) by more effectively utilizing native and introduced parasites and predators. Thus, research along these lines has been initiated to explore the possibilities of effectively using parasites and predators in controlling the greenbug. In the present research on the greenbug, the effectiveness of parasite action will be studied.

I would like to express my sincere appreciation and gratitude to Dr. R. D. Eikenbary, Department of Entomology, for his advice and constructive ideas received in directing and preparing this manuscript; to Dr. R. R. Walton and Dr. Ken Starks, Department of Entomology, Dr. R. D. Miller, Department of Zoology, and Dr. R. N. Payne. Department of Horticulture, for their critical reading of the manuscript and their many helpful suggestions. Appreciation is extended to Dr. Charlie Rogers, Department of Entomology, for his invaluable help with the photography in this research.

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To Wilber and Pauline Hight, the wisest and best parents in the whole world, I would like to express my deepest and sincere gratitude and appreciation. They deserve the degree more than I.

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INTRODUCTION

During 1968, heavy greenbug populations were found on sorghum throughout most of the sorghum producing states west of the Mississippi River. The Cooperative Economic Insect Report, USDA (1969), reported greenbugs infested over 7 1/2 million acres of sorghum and an estimated loss to sorghum production exceeded 68 million dollars in infested states. In the Oklahoma Panhandle, colonies of aphids appeared in late June; however, growers did not notice heavy populations until late July, 1968. Epidemic proportions were reported by July 24 in the three panhandle counties. Concern by entomologists in the states involved saw the establishment of a state and regional project to investigate the use of biological control as an agent in controlling this pest. Langston (1970) and Raney et al. (1970) have investigated the longevity, fecundity, development period, sex ratio, and host preference of a nature parasite *Aphelinus nigritus* (Howard) and *A. asychis* (Walker) an imported parasite. Jackson (1971) conducted a survey of Oklahoma during 1968-1970 on the greenbug and other species commonly associated with sorghum or small grains. *Lysiphlebus testaceipes* (Cresson) was the most abundant parasite. *A. nigritus* and *A. varipes* were collected for the first from field collections in Oklahoma. This research is a continuation of that project and is designed to determine what effect the native parasite *L. testaceipes* has on the sorghum greenbug and to help give some indication as to the possibilities of mass rearing this parasite for biological control of the greenbug.

LITERATURE REVIEW

The greenbug, Schizaphis graminum (Rondani), is considered to be one of the most injurious insects attacking small grains in the central and southwestern states. Webster and Phillips (1912) reported that the first record of its appearance was dated 1847 and Rondani described it in 1852. Its first known appearance in America was noted in 1884.

In 1968, sorghum crops were severely damaged by the greenbug for the first time in Arizona, California, Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, and Texas (Jackson et al. 1970, Wood and Chada 1969). Sorghum was first recorded as a host for the greenbug by Passerini in 1863 (Webster and Phillips 1912). Kelly (1917), and Hays (1922) reported the greenbug damaged sorghums in 1916. However, the first generation was all that seemed to survive.

The greenbug attacking sorghum, hereafter designated as biotype C, is taxonomically similar to biotypes A and B which attack wheat. However, it differs in several ways: it is lighter green in color; the cornicles have little or no black on their tips; cornicle tips are not expanded and wrinkles are present throughout their entire length. Biotypes A and B have wrinkles present on basal portions only (Wood and Chada 1969, Daniels and Jackson 1968, and Harvey and Hackerott 1969a). Evidence that this aphid was a new strain or biotype was based on its ability to survive, develop and reproduce on nearly mature sorghum at temperatures as high as 110° F (Wood and Chada 1969, Harvey and Hackerott 1969b).

The parasite *Lysiphlebus testaceipes* (Cresson) is often mentioned in conjunction with greenbug outbreaks. During the greenbug outbreak of 1916, *L. testaceipes* were found in winged forms of the greenbug as they made their flight northward from sorghum and corn fields (Kelly 1917). Webster and Phillips (1912) stated that *L. testaceipes* attacks all stages of the greenbug. Pergande (1902) attributed the destruction of large colonies of aphids to *L. testaceipes*, and Sekhar (1957) reported this parasite effective in controlling the 1939 greenbug outbreak. In 1968, Wood and Chada (1969) reported that this parasite, along with predators, had nearly eliminated an infestation of greenbugs on a check plot of sorghum that was being used to screen insecticides. In a 1969 survey, Jackson, et al. (1970), reported *L. testaceipes* was the most abundant parasite of the greenbug in Oklahoma but it was not abundant until early August.

Spencer (1926) reported *L. testaceipes* will bring about a cessation of reproduction of an aphid on the third day, or thereabouts. The mating, oviposition and discrimination of hosts by *L. testaceipes*, has been treated in some detail by Sekhar (1957). Webster and Phillips (1912) collected a large amount of data concerning nearly every phase of its development. Their experiments were conducted in a slightly heated room where temperatures ranged from 50-80° F. However, there has been little controlled laboratory work done with *L. testaceipes* and its effects on greenbug.

METHODS AND MATERIALS

The fecundity of the parasitized greenbug was determined at constant temperatures of 70 and 80° F and an alternating temperature of 70-90° F. The alternating temperature was maintained for 12 hours at 70° and 12 hours at 90° F. The temperature was maintained in controlled environmental chambers with a 12-hr photoperiod yielding approximately 1110 ft. candles per chamber. Illumination was provided by four 25 watt incandescent lamps and Sylvania's Lifeline FR40CW-235 florescent lamps. The aphids were reared and maintained on caged RS-610 sorghum plants growing in 4-inch pots. The cages were patterned after the ones reported by Raney et al. (1971). The soil surface under each plant was covered with fine white sand to facilitate the search for the aphids dropping or crawling on the soil. *L. testaceipes* was used as the test parasite.

To obtain aphids of known age, twenty adult greenbugs were placed on a sorghum plant for 12 hours (Fig. 4) and then removed. Fig. 1 shows a population of greenbugs 12 hours after the adults were placed on the plant. The offspring from these adults were then sized and number reduced to 14 to obtain uniformity among the aphids. At 80 and 70-90° F, five age groups of aphid hosts were used: (1) one day old (24 hr); (2) two days old (48-54 hr); (3) three days old (72-78 hr); (4) four days old (96-112 hr); and (5) five days old (120-130 hr). Seven days were required to obtain adult aphids at 70° F. The ages of aphids used in the 70° tests were the same as those for the 80 and 70-90° test, except the periods of (6) six days old (144-150 hr) and (7) seven days old (168-172 hr) were continued to obtain adult aphids. This method of timing of the ages of the aphid was similar to that used by Fox et al. (1967). The fecundity of the parasitized greenbug was measured by observing three replicates of 14 aphids per entry, making a total of 42 aphids/age.

Four 1- to 2-days old mated L. testaceipes females (Fig. 2) were introduced into the cage just prior to or at the beginning of 12 hours of light. The parasites were removed after 12 hours. A mouth aspirator was used to transfer the parasites into and out of the cage through a hole in the side of the cage. Using a small soft artist's brush, the aphids were transferred individually to another plant after parasitization. The nymphs were observed each day until they developed into mummies (parasitized greenbugs). An aphid was considered to be a mummy when the exoskeleton had become an opaque off-white. The mummies were left on the plant to develop and the emerging parasites were collected, sexed and recorded. Fig. 3 shows the profile of a male parasite while Fig. 4 and 5 show the female in the act of parasitization.

RESULTS AND DISCUSSION

L. testaceipes readily attacks all ages of the greenbug and may "sting" one several times as was reported by Webster and Phillips (1912). Often the ovipositional thrust and/or "stinging" of the parasite was so forceful that the smaller aphids (1- to 3-days old) were knocked off the plant. Fig. 6 shows the average per cent of sorghum greenbugs forced off the plant by L. testaceipes. Aphids 4- to 5-days old in close proximity to a parasite frequently walked off or dropped from the plant. Stary (1970) reported that other aphid species react very promptly to a parasite female by pulling out their rostrum from the plant, running away and falling from the plant. An average of 40% of the total aphids crawled back to the plant and began feeding. Aphids of all ages "stung" three or more times and knocked off the plant usually died, thus reducing the number of mummies produced below the number of parasitized aphids.

Table 1 shows the effect of age and temperature on the reproductive life of the parasitized sorghum greenbug. The reproductive life of parasitized greenbugs indicates when the first aphid at a certain age began reproducing and the day maximum progeny was produced at a certain age. Aphids parasitized at age 4- to 7-days at 70° F and aphids of ages 4- to 5-days at 80 and 70-90° F produced a near normal amount of progeny (3 to 5/day) until approximately the 2nd to 3rd day after parasitization, then the reproduction declined to zero. The maximum reproductive life of parasitized aphids was 5 days. A few aphids at all ages and temperatures which developed into mummies did not reproduce.

Aphids that were 1- to 3-days old when parasitized did not live to reproduce. Fig. 7 illustrates the average progeny produced per parasitized aphid for each age of the aphid at each temperature. The average number of progeny per parasitized aphid increased with the aphid age for those aphids that were four days old or older when parasitized at all temperatures tested. Winged greenbugs frequently occurred at 70° F. At this temperature approximately 70% of the 6-day old parasitized greenbugs became winged and produced 3.8 progeny/aphid. Approximately 68% of the 7-day old greenbugs were winged and produced 3.1 progeny/aphid as compared with 3.8 progeny/aphid for nonwinged aphids. At 70° F the 4- and 5-day old parasitized greenbugs did not develop wings; however, wing pads could be seen upon close observation. Very few winged parasitized greenbugs appeared at 80 and 70-90° F and these usually produced from 2-3 fewer offspring than nonwinged aphids.

Fig. 8 illustrates a theoretical average reduction of greenbug population resulting from parasitism. If one mature greenbug reproduces an average of 4 progeny/day for 25 days and the reduction due to parasitization is likewise figured, then the average percent reduction may be calculated. Population reduction would be 100% for all parasitized greenbugs from 1- to 3-days of age while a reduction of 85% or better would be possible for all other ages excepting those parasitized at 7-days old at 70° F, where a 53% reduction was obtained. Table 2 represents a theoretical model of an aphid population originating from one greenbug under laboratory conditions.

Table 3 lists the development of _L. testaceipes_ for each age of aphid held at each temperature. The egg-mummy category indicates the average period from parasitization to appearance of the mummy. The mummy-adult category was the time for pupal development, and the egg-adult category was the time from parasitization to adult emergence. The egg-mummy period was variable at each temperature. The time of parasitization probably influenced this; however, there was a general tendency for 1-day old aphids to take a day longer to develop into mummies at the 80 and 70-90° F temperatures. Mummies developing at 70° F required an average of 2 days longer in development. The egg-mummy period required from 3 to 4 days regardless of temperature. The egg-adult period varied from 10 to 14 days. Parasites developing at 70° F took slightly longer to develop.

The age of the aphid when parasitized appeared to have no influence on the emergence of the parasite. Emergence of parasites from all ages of aphids was high except for the 1-day old aphids at 80° F. The mummies of one replicate were removed from the plant and approximately 55% of the parasites did not emerge. Damage to the mummies was the apparent cause since all other replicates of mummies were left on the plant until adult emergence, and a reduction of parasite emergence was not noted. The percentage of females tended to be slightly less for parasites developing from the 1-day old aphids. The parasites emerging from 1- and 2-day old aphids were notably smaller in size. Hafez (1961) recognized apparent differences between adults of _Diacretiella rapae_ reared from various instars in the laboratory. The F_1 adult parasites appeared to have no effect on parasite vitality.

In the laboratory, _L. testaceipes_ reduced the number of aphids occurring on the plant in two ways. The aphids parasitized in the first three instars died and produced no offspring, while the aphids parasitized during the 4th and 5th instars at 80° F produced an average of

2.5 and 4.3 offspring per aphid, respectfully.

There should be greater aphid mortality as a result of parasite activity in the field than in the laboratory. For instance, in the laboratory occasionally all of the aphids on a plant would drop or be knocked off of the plant as a result of the parasite's ovipositional thrusts or its walking near the aphids. While in the laboratory, most of the dislodged aphids returned to the plant and survived, it is suspected that under field conditions, a large portion of the aphids that fell to the ground during June, July and August would die as a result of the high soil temperatures.

In the laboratory L. testaceipes appears to be a good parasite of the greenbug in that: (1) it readily attacks all ages, (2) reduces the fecundity of the greenbug, (3) adult emergence is excellent, (4) healthy adults develop from all ages, and (5) the ratio of males to females is good. This parasite has been a factor in controlling past outbreaks of the greenbug and its potential as an effective agent in controlling the greenbug is good.

Future work in the techniques for mass rearing, storing, and determining the level of greenbug infestation at which L. testaceipes should be released needs to be investigated.

SUMMARY

In the laboratory _L. testaceipes_ reduced the number of aphids occurring on the plant in two ways. Aphids parasitized in the early instars died and produced no offspring. Aphids parasitized during the 4th and 5th instars at 80° F produced an average of 2.5 and 4.3 offspring per aphid, respectfully. By comparing nonparasitized greenbugs that will produce an average of 4 per day for 25 to 30 days with parasitized greenbugs a notable reduction of progeny is observed.

Female parasites developed from 1-day old parasitized greenbugs, although the greater percentage were males. The life cycle of the parasite varied from 10 to 14 days. The maximum reproductive life of the parasitized greenbug varied from 0 to 5 days versus about 25 to 30 days in nonparasitized greenbugs.

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APPENDIX

TABLE I

THE EFFECT OF AGE AND TEMPERATURE ON THE REPRODUCTIVE LIFE OF THE PARASITIZED SORGHUM GREENBUG

Temperature	Age of parasitized aphids (days)[a]	No. of parasitized aphids	Progeny of parasitized aphids	Reproductive life		
				Start	Maximum reproductive day	End
70° F	1	30	0	-	-	-
	2	31	0	-	-	-
	3	41	0	-	-	-
	4	14	22	8	9.2	10
	5	30	61	7	7.4	10
	6	28	94	7	7.6	9
	7	11	50	7	7.6	10
80° F	1	32	0	-	-	-
	2	26	0	-	-	-
	3	30	0	-	-	-
	4	26	65	5	7.0	10
	5	25	106	6	7.4	10
70-90° F	1	22	0	-	-	-
	2	38	0	-	-	-
	3	28	0	-	-	-
	4	25	20	5	5.3	7
	5	23	99	6	6.8	9

[a] Three replicates, 14 aphids/replicate.

TABLE 2

A THEORETICAL MODEL OF AN APHID POPULATION ORIGINATING FROM ONE GREENBUG UNDER THREE CONTROLLED TEMPERATURES[a/] IN THE LABORATORY

Days after 1st nymph born	Non-parasitized	Parasitized by *L. testaceipes*						
		3rd instar	4th instar			5th instar		
	80°	70°	70°	80°	70-90°	70°	80°	70-90°
5	21	1.9	3.4	2.5	.8	13.6	4.3	4.3
10	280	24	31	32	10	136	56	56
15	1,900	150	207	203	65	664	348	348
20	9,424	690	983	933	298	3,808	1,604	1,604
25	40,583	2,027	4,151	3,903	1,249	15,926	6,712	6,712

a/ Temperature expressed in Fahrenheit

TABLE 3

THE EFFECT OF TEMPERATURE AND AGE OF THE PARASITIZED SORGHUM GREENBUG ON THE DEVELOPMENT, EMERGENCE, AND SEX RATIO OF L. TESTACEIPES

Temperature	Age of parasitized aphid (days)[a]	Egg-mummy (days)	Mummy-adults (days)	Egg-adult (days)	% emergence	% female
	1	9.0	3.4	12.3	100	47
	2	8.3	4.2	12.5	83	50
	3	8.3	3.9	12.2	100	61
70° F	4	8.2	4.3	12.5	100	79
	5	9.1	4.4	13.5	96	55
	6	8.8	5.6	14.4	89	60
	7	9.3	4.7	14.0	100	90
	Average	9.1	4.1	11.5	95	63
	1	8.4	3.3	11.7	71	35
	2	7.4	3.3	10.6	96	52
80° F	3	6.9	3.3	10.3	86	62
	4	6.8	3.6	10.4	96	60
	5	7.5	3.6	10.1	88	50
	Average	7.4	3.4	10.6	87	52
	1	8.2	3.5	11.7	86	57
	2	7.8	3.3	11.1	97	38
70-90° F	3	8.0	3.7	11.8	92	73
	4	6.2	4.2	10.4	80	70
	5	6.8	3.8	10.6	100	87
	Average	7.4	3.7	11.1	91	65

[a] Three replicates, 14 aphids/replicate.

Fig. 1 The adults and progeny of the sorghum greenbug.

Fig. 2 The mating act of L. testaceipes.

Fig. 3 The profile of a male L. testaceipes.

Fig. 4 Parasite attacking an adult greenbug.

Fig. 5 Parasite attacking a one-day old greenbug.

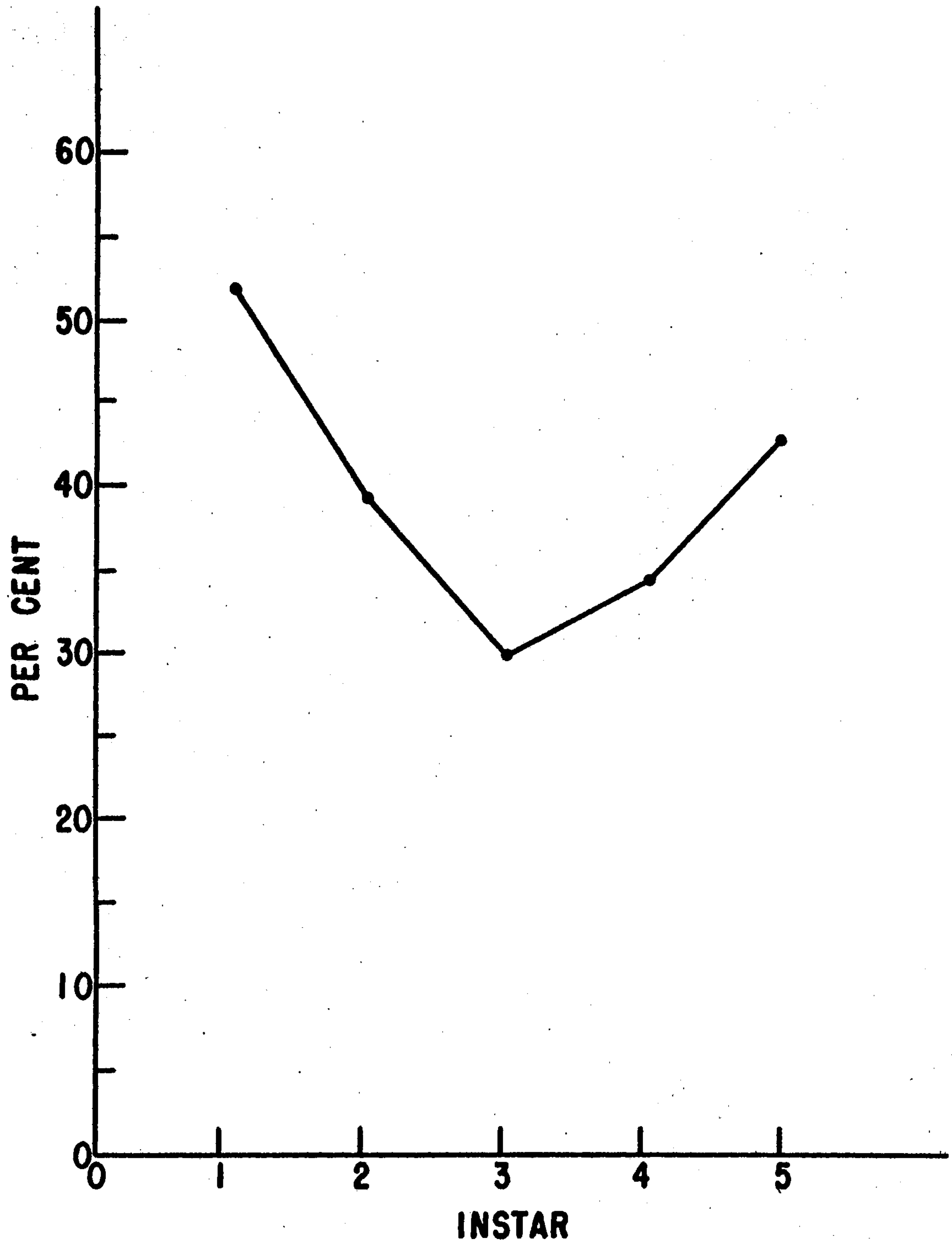

Fig. 6 Average percent of sorghum greenbugs forced off the plant as a result of parasitization and activity of *L. testaceipes*.

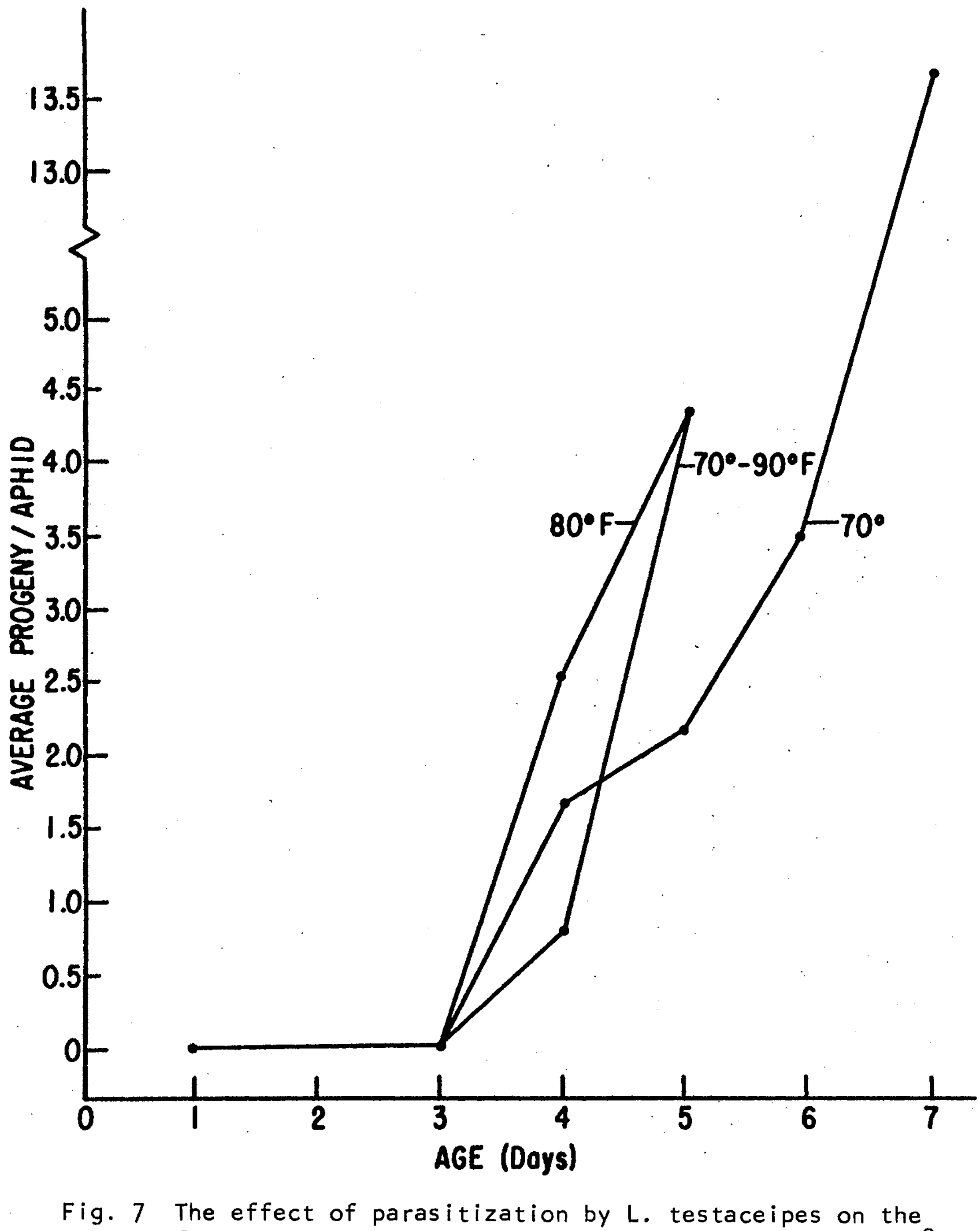

Fig. 7 The effect of parasitization by L. testaceipes on the fecundity of the sorghum greenbug at 70, 80 and 70-90° F.

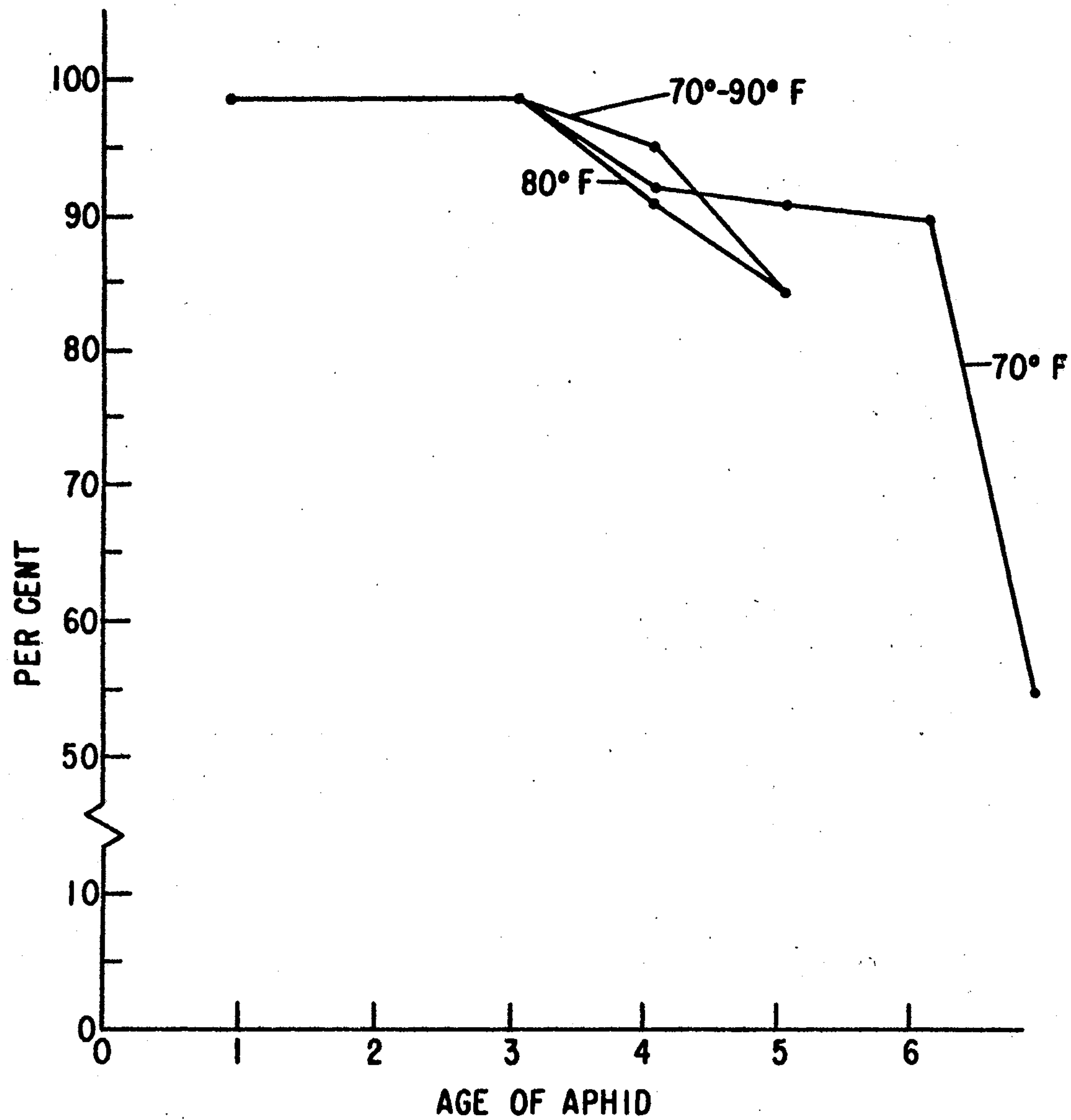

Fig. 8 Theoretical average percent reduction of sorghum greenbug population due to parasitization by _L_. _testaceipes_.

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Thesis: THE EFFECT OF PARASITISM BY _LYSIPHLEBUS TESTACEIPES_ (CRESSON) ON THE FECUNDITY OF THE SORGHUM GREENBUG, _SCHIZAPHIS GRAMINUM_ (RONDANI)

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