EFFECT OF VARIOUS TEMPERATURES ON TWO STRAINS OF GREENBUG (TOXOPTERA GRAMINUM (ROND.)) AND ITS PARASITES

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INTRODUCTION

The importance of the greenbug, Toxoptera graminum (Rond.), to the world economy can be recognized by its vast geographical distribution as an economic pest, and by the wide range of the members of the grass family that serve as hosts.

Natural control of the greenbug has received considerable attention. It has been found that this insect is effectively controlled in certain temperature ranges by its parasites and predators. Various workers have established the relationship of different temperature gradients to both the greenbug and its parasites.

In these experiments the minimum, optimum and maximum temperatures have been established for the reproduction of two strains of the greenbug on both susceptible and resistant host plants, and for the parasitization of one strain by Aphelinus nigritus How. and Aphidius testaceipes (Cress.).

REVIEW OF LITERATURE

Field Greenbug Strain

Toxoptera graminum (Rond.) of the order Homoptera, family Aphididae, is most commonly known as the greenbug. In 1852, Dr. C. Rondani of Italy described this insect, giving it the name Aphis graminum. It was placed in the genus Toxoptera by Passerini in 1863. Pergande (1902) noted that the earliest record of this insect in the United States occurred in June 1882.

This pest is widely distributed and its range includes large parts of North, Central and South America, Europe, Asia and Africa. The greatest damage to small grains occurs in southern United States, Italy, Hungary, southern Russia and southern Africa.

The host plants of the greenbug appear to be confined to the Gramineae. Patch (1938) listed 62 grass plants on which the greenbug has been observed. Dahms et al. (1954) subjected 23 grasses to greenbug infestation. Eleven of these species had not been recorded by Patch. Daniels (1960) listed 20 species of grasses on which greenbugs have been observed reproducing in the Panhandle area of Texas. Five of these species were not mentioned previously by either Patch or Dahms et al.

Greenbugs are much more injurious in proportion to their numbers than are other grain aphids. Wadley (1929) believed that an injection

of a chlorophyll-destroying enzyme into the plant cells rather than the extraction of plant juices was the cause of the damage. Tate (1937) described the method of penetration, formation of stylet sheaths and source of food supply of these aphids. Chatters and Schlehuber (1951) confirmed the statement of Wadley (1929).

There have been severe outbreaks of the greenbug in the United States, mainly in Texas, Oklahoma, and in some parts of Colorado, Kansas and Nebraska. Kelly (1917) listed the major outbreak years as 1890, 1901 and 1907, and described the outbreak of 1916. Ainslie (1926) described the severe outbreak that occurred in Minnesota during that year. Dahms (1951) noted that there have been 14 outbreaks in this country, the most serious of which occurred in 1942 when more than 61 million bushels of grain valued at 38 million dollars were lost in Texas and Oklahoma alone. Painter et al. (1954) listed severe outbreaks of the greenbug in 1907, 1916, 1934, 1939, 1949 and 1950. The greenbug was referred to by Reitz (1954) as one of the five major insect pests attacking wheat.

Painter (1954) stated that greenbugs are most likely to become abundant when a cool, moist summer is followed by a mild winter and a late, cool spring. Various workers have established different temperature ranges for the minimum, optimum and maximum rate of reproduction of the greenbug. These differences could possibly be due to different strains of the insect or to the various host plants used in the studies. Hunter and Glenn (1909) found that the optimum temperature for the species is about 20° C. (68° F.). As the temperature increases the rate of reproduction gradually decreases until a maximum temperature of 29° C. (84.2° F.) is attained. At 32° C. (89.6°) the aphids cease feeding and death ensues at 37.5 to 40° C. (99.5 to 104° F.). Sanderson (1910) in

in his experiments with temperatures on various insects found that greenbug development can take place at 1.65° C. (34.97° F.), and the lethal minimum temperature for the pest is -8.33° C. (17° F.). Headlee (1914) recorded results with constant temperatures of 50, 60, 70, 80 and 90° F., and found reproduction and development most rapid at 80° F. Wadley (1931) tested the greenbug for maximum lethal temperatures and found that above 30° C. (86° F.) the aphids were restless; above 35° C. (95° F.) they often abandoned the leaf and moved around frantically. Their movements were aimless at 41° C. (105.8° F.) and ceased at 42° C. (109.4° F.). The nymphs were killed at 35° C. (95° F.). He found that the optimum for reproduction was approximately 22 to 23° C. (71.6 to 73.4° F.).

Lefroy (1908) and Moore (1914) noted that the greenbug had difficulty in living through the summer in India and South Africa. They also noted a root-feeding habit in hot weather. Wadley (1935) observed a similar phenomenon. Dahms (1951) stated that the greenbug can reproduce and develop at temperatures from 40 to 100° F., but that the optimum is between 55 and 65° F. He further stated that temperatures as low as 5° F. or as high as 107° F. are lethal. Daniels et al. (1956) determined that the greenbug can reproduce moderately well at 40° F., and at a much more rapid rate at temperatures between 55 and 80° F. He believed that lethal temperatures are as 0° F., or as high as 105° F. English (1908) observed greenbugs in Oklahoma giving birth to young when temperatures were below freezing.

Headlee (1914) found that greenbugs were little affected by relative humidities ranging from 37 to 100 percent. Wadley (1931) confirmed this and stated that sap-feeding insects evidently are not affected directly by humidity.

Greenhouse Greenbug Strain

In connection with a project at the Oklahoma Agricultural Experiment Station on breeding small grains for resistance to the greenbug, Dahms (1948) reported possible differences in strains of this insect with respect to the interaction between insects and plants. Wood (1958) studying greenbug resistance in the greenhouse at Stillwater during the fall of 1956, found a new biotype which he called the greenhouse strain. This strain was able to destroy wheat plants which were resistant to the field strain. He noted that the greenhouse greenbug strain is comparatively larger in size than the common field strain when both are cultured on resistant wheat plants. When cultured on susceptible lines there is no difference in size.

Parasites of the Greenbug

Aphidius testaceipes (Cress.) belongs to the order Hymenoptera, family Braconidae. This species was first described by Cresson in 1879 as a parasite of the "cotton aphis, wheat aphis and orange aphis". Webster and Phillips (1912) identified as many as 30 different hosts of this parasite and believed that there were probably many others.

Various authors have suggested different temperatures for the optimum activity of A. testaceipes. Glenn (1909) showed that the adult parasites could survive at temperatures as low as 17° F., and at 51° F. the parasite actively sought out its host. He believed that 70° F. was optimum for this parasite. Above this temperature it showed a greater tendency to take flight than to oviposit. Sanderson (1910) found that death of the parasite occurred at -8.33° C. (17° F.), that it was inactive at 5° C. (41° F.) and that the optimum for the species was 20 to 35° C. (68 to 95° F.). Commenting on the disastrous outbreaks of the

greenbug, Webster and Phillips (1912) stated that cool temperature was the chief cause since the parasite is inactive at temperatures below 56° F. Dahms et al. (1951) determined that the degree of activity of the parasite was very low at temperatures under 65° F. Painter et al. (1954) and Fenton (1952), commenting on the biological control of the greenbug, stated that this insect can bring forth living young at about 40° F., while its parasites do not oviposit until the daily temperature reaches about 65° F. Wood (1958) noted that parasitization by this species is restricted to the later instars and only when temperatures are above 56° F.

Sanborn (1916) believed that, if the average winter temperature exceeded 50° F., the parasite would control the greenbug before the latter could become serious. If the temperature fluctuated above and below a mean of 50° F., the greenbug would cause severe damage due to the inactivity of the parasite.

Aphelinus nigritus How. (Hymenoptera: Eulophidae) was first described by Howard in 1908. Webster (1909) reared it from Toxoptera sp. According to Webster and Phillips (1912), this parasite has been found in Kansas, Minnesota, New Mexico and South Carolina. Subsequent collections have been made by other workers in Arizona and California. Its hosts were listed as the rusty plum aphid (Hysteroneura setariae (Thos.), Pseudococcus sp. and Toxoptera sp. Wood (1958), in an attempt to determine new hosts among the more important aphids that attack small grains and other crops in Oklahoma, found additional hosts which included Toxoptera graminum (Rond.), Rhopalosiphum fitchii (Sand.) and Rhopalosiphum maidis (Fitch.). Wood (1958) further observed that A. nigritus parasitized all stages of its hosts at temperatures as low as 42° F.

FECUNDITY STUDIES OF TWO GREENBUG STRAINS

Materials and Procedures

Ward barley and Dickinson Selection 28-A wheat seedlings were grown in 6-inch flower pots. The soil was a mixture of two parts of black soil, one part sand and one part peat moss. This was passed through a 1/8-inch mesh screen and then thoroughly mixed. The plants growing in the flower pots were covered with cylindrical cellulose nitrate cages having 80-mesh muslin screen tops to provide ventilation.

When the seedlings were about 6 inches in height a known number of apterous female greenbug adults of both strains were transferred with a damp camel's hair brush and cultured separately on Sel. 28-A wheat and Ward barley. After the adults had reproduced on the respective cultures for one day, they were removed with the aid of a damp brush. The nymphs were observed periodically until maturity was reached. As soon as reproduction occurred, individual aphids from the respective cultures were transferred to single seedlings grown in 8-ounce paper ice cream cups. Small holes were made in the bottom of the cups with an ice pick to facilitate water absorption.

The test plants infested with individual aphids were confined within small plastic cages. Five replications of each of the following categories were used: field strain on Sel. 28-A wheat; field strain on Ward barley; and greenhouse strain on Sel. 28-A. The infested plants were transferred to constant temperature cabinets which were maintained at given temperatures, and after a 24-hour period the new-born young

produced were counted. Five days later the plants were removed and the total number of young was recorded. The number of nymphs appearing during the first 24-hour period was subtracted from the total, so that the remaining nymphs were those produced during the last four days at the respective temperatures. Thus, by excluding the nymphs born during the first 24 hours, a preconditioning period of 24 hours was not included in the final count. After completion of each test, the plants were reinfested in the same manner in a duplicate test at the same temperatures. Thus, there were 10 replicates in identical experiments conducted at temperatures ranging from 50 to 100° F. at intervals of 5° F. The plants within the cabinets were exposed to continuous fluorescent lighting. The relative humidity averaged 40%.

Results

The total number of nymphs produced by 10 aphids in 4 days at the respective temperatures is shown in table 1. From this the average number of nymphs from a single aphid in a 24-hour period at the respective temperatures was calculated (Fig. 1).

There were increases in fecundity with each 5-degree increase in temperature above 35° F. for both strains of the greenbug on resistant and susceptible plants until the respective optima for reproduction were reached. The field strain had approximately the same fecundity on both resistant and susceptible hosts at lower temperatures (35, 40 and 45° F.), but, at higher temperatures, survival and reproduction were very much retarded on resistant as compared with susceptible plants.

The highest average fecundity was noted when the greenhouse strain fed on Sel. 28-A wheat at a temperature of 75° F. The highest average fecundity of the field strain occurred at 70° F. while feeding on (susceptible) Ward barley, and at 60° F. on (resistant) Sel. 28-A wheat.

TABLE I

TOTAL NUMBER OF NYMPHS PRODUCED BY TEN ADULT APTEROUS *TOXOPTERA GRAMINUM* (ROND.) IN A FOUR-DAY PERIOD AT VARIOUS CONSTANT TEMPERATURES. STILLWATER, OKLAHOMA. 1960.

Degrees F.	Greenhouse strain	Field strain	
	Sel. 28-A wheat	Sel. 28-A wheat	Ward barley
35	0	0	0
40	3	2	2
45	9	8	11
50	32	24	43
55	60	32	61
60	76	40	80
65	87	20	88
70	94	20	90
75	98	16	80
80	78	6	34
85	26	3	6
90	8	0	5
95	3	0	1
100	0	0	0

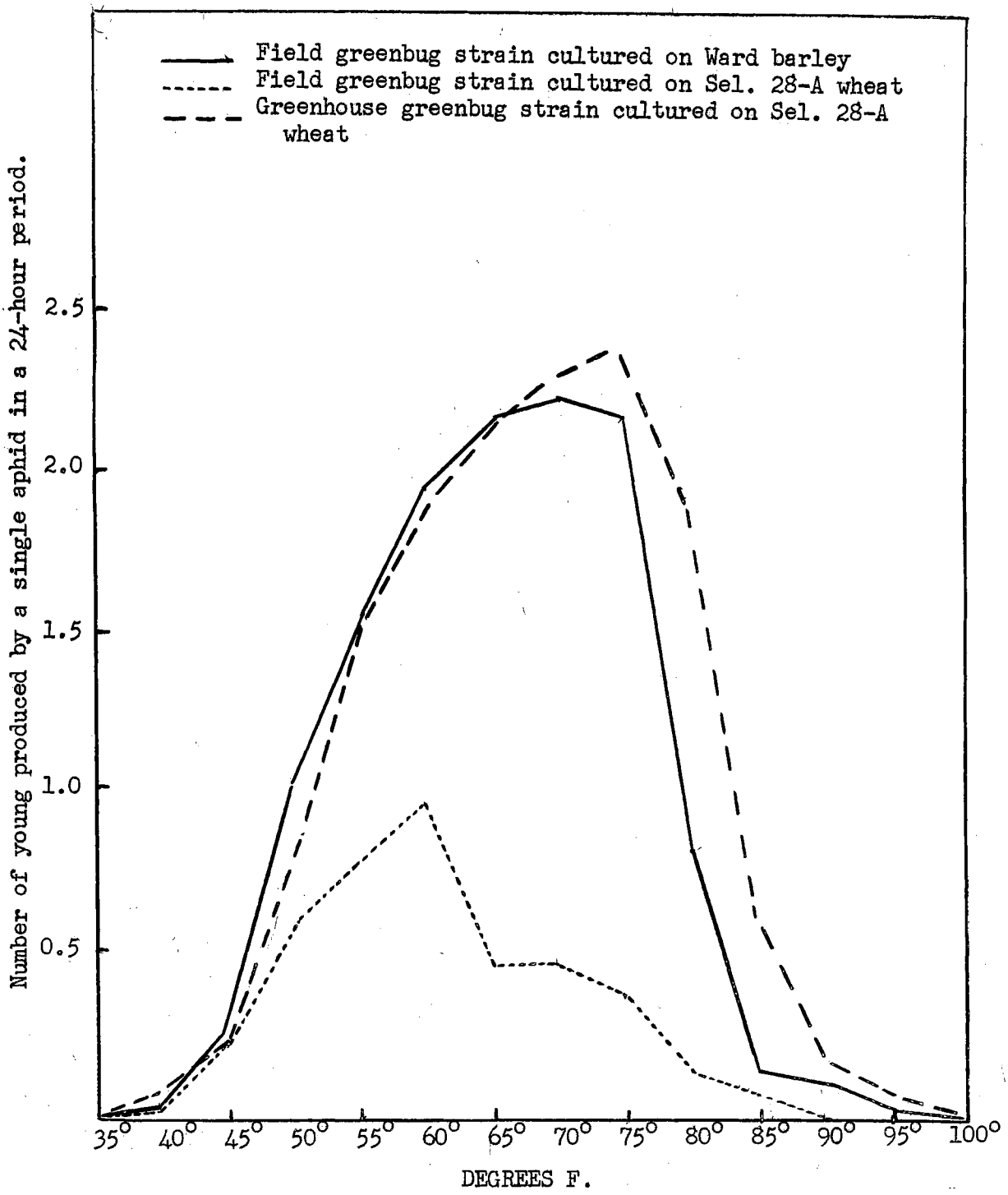

Fig. 1.--Effect of various constant temperatures on the daily rate of reproduction of two strains of the greenbug, Toxoptera graminum (Rond.). Stillwater, Oklahoma. 1960.

The field strain on Sel. 28-A had a lower reproductive rate than on barley at all temperatures above 40° F. (Fig. 1). The optimum temperatures for reproduction were also different on the two hosts. Although the minimum temperatures remained unchanged, large differences occurred at the higher temperatures. Few nymphs and adults could survive on resistant plants at high temperatures. The maximum temperature for reproduction of the field strain on Sel. 28-A wheat was 85° F. and on Ward barley, 95° F.

Interpretation of Results

The fecundity of the greenbug increased with increased temperature in both strains until the optima for reproduction were reached. The fecundity of the greenhouse strain on Sel. 28-A was highest at 75° F. and that of the field strain at 60° F. Further increases in temperature with both strains decreased fecundity.

Observations made at high temperatures (85 to 90° F.) showed that the number of nymphs produced by the respective strains in the first 24-hour period (preconditioning) was very high, being even higher than that at optimum temperatures. However, the nymphs could not survive at these temperatures for a period of 4 days. This increased reproduction is probably the result of high temperatures acting on the physiology of the greenbug so as to increase the metabolic activity and thus force the previously formed nymphs to emerge prematurely, or causing physiological changes in the plant which might alter the plant sap available to the aphid.

The greenhouse strain of the greenbug appeared to have a very high reproductive potential on the resistant wheat variety at all temperatures, in comparison with that of the field strain (Fig. 1). The optimum

temperature for reproduction of the greenhouse strain is also higher than for the field strain. The fecundity of the greenhouse strain on resistant wheat was very close to that of the field strain on susceptible barley. This is a clear indication that Sel. 28-A is not resistant to the greenr house greenbug strain at any temperature.

The results obtained by feeding the field strain of greenbug on susceptible barley and resistant wheat are similar to those derived by Hackerott and Harvey (1959) working with the spotted alfalfa aphid. Fecundity was retarded relatively more at high, than at low temperatures on the resistant plants as compared with susceptible plants. The fecundity of the field greenbug strain at 40° F. on both susceptible and resistant plants was the same and there was little difference at 45° F. Larger differences in the fecundity of the field strain on the different hosts were observed at temperatures above 50° F. The difference in optimum temperature for the field strain on resistant and susceptible plants is similar to that indicated for the pea aphid by Dahms and Painter (1940). Their results showed that the optimum temperature for reproduction and survival was several degrees higher for susceptible than for apparently resistant alfalfa plants. They suggested that a deficiency in available food for pea aphids in the resistant plants would be more detrimental at high temperatures, since the metabolic rate of the aphids would be increased. This suggestion may also explain the differential response of the field strain of greenbug on susceptible and resistant plants.

In considering the relative merits of evaluating plants for resistance at different temperature levels, it appears that resistant wheat plants may be distinguished from susceptible ones at all temperature

levels studied, but more readily at higher than at lower temperatures. Hackerott and Harvey (1959) suggest that it appears that the higher the level of resistance in the plant at high temperatures, the more resistance it will exhibit at low temperatures.

It can be concluded that temperature is an important factor affecting the reaction of the greenbug to resistant plants, and also that sooner or later aphid biotypes could be produced. On a few occasions the presence of biotypes able to make some use of resistant plants as food has also been observed by Painter (1930), Harrington (1943), Dahms (1948) and Cartwright and Noble (1947).

As demonstrated in this experiment, there was a difference in reproductive reaction to temperature by biotypes; there may also be possible morphological differences or even differences in reaction to natural substances in the environment such as carbon dioxide and soil fertility levels. The different degrees of injury to resistant Sel. 28-A wheat plants ascribed to the two biotypes suggests that there are differences in the salivary injection of these biotypes. As may be recalled, Wadley (1929) stated and later Chatters and Schlehuber confirmed, that the injection of a chlorophyll-destroying enzyme into the plant cells rather than the extraction of plant juices was the cause of the damage. Disease transmission by the biotypes has also been observed to vary. For example, Singh and Young (unpublished 1960) while working with the apple grain aphid in barley yellow dwarf virus transmission studies found that the greenhouse greenbug strain was a much better vector of that virus than was the field strain.

TEMPERATURE STUDIES FOR PARASITIZATION

Materials and Procedures

An effort was made during the spring of 1960 to determine, by greenhouse studies, the effect of various temperatures on the oviposition of Aphelinus nigritus How. and Aphidius testaceipes (Cress.). The host used for parasitization was Toxoptera graminum (Rond.).

Cultures of the parasites were separately maintained in the greenhouse on greenbugs caged on plants growing in flower pots. Approximately 20 plants of Ward barley were grown in each 6-inch pot and infested with greenbugs. When these became abundant, a few parasites were liberated and each pot was covered with a transparent cage. Host aphids parasitized by Aphelinus nigritus became jet black within a few days; whereas host mummies of Aphidius testaceipes became light golden in color. In approximately 3 weeks adult parasites emerged from the mummies and were used for experimental purposes. By this method regular cultures of parasites were maintained in several pots to be ready for use when required.

Three Ward barley seeds were planted in 8-ounce paper ice cream cups, and at the two-leaf stage of growth were thinned to one healthy plant per cup. When the plants were approximately 3 inches in height, 10 mature apterous aphids were caged on each plant. These were used as host material for parasitization at the respective temperatures.

The parasites were collected from the cultures by means of an aspirator and then inactivated at 35° F. Twenty parasites of each species

were placed in vials containing several aphids, which provided them with honeydew for food. These were held in the temperature cabinets for acclimation for a 24-hour period, after which the parasites in the vials were again inactivated and a single female was caged with 10 aphids on each test plant. At each temperature 10 replicates were used, and these were left in the cabinets at the respective temperatures for a 24-hour period. The parasites were then removed by means of an aspirator and the caged plants containing the parasitized and unparasitized aphids were removed to the greenhouse for further development. After a lapse of eight days, counts were made to determine the number of mummies obtained from each parasite.

The temperatures at which the experiment was conducted ranged from 40 to 95° F. in increments of 5° F. The temperature in the greenhouse averaged approximately 70° F. Plants were exposed to natural lighting in the greenhouse. Experiments involving the effect of various temperatures in the cabinets were conducted under fluorescent lighting. The relative humidity in the temperature cabinets averaged approximately 50%.

Results

Data on the effect of oviposition by the two parasites at various temperatures are shown in table 2 which gives the total number of aphids parasitized at each temperature. From this the average number parasitized by a single parasite at various temperatures was calculated (Fig. 2).

Aphelinus nigritus How.-- No parasitization was found at a temperature of 40° F. and very little at 45° F. There was an increase in parasitization above 45° F. until the optimum temperature was reached. The greatest average parasitization was at 65° F., and at higher temperatures

TABLE II

NUMBER OF GREENBUGS, TOXOPTERA GRAMINUM (ROND.), PARASITIZED PER DAY BY TWO HYMENOPTERONS AT CONSTANT TEMPERATURES. STILLWATER, OKLAHOMA. 1960.

	Degrees F.										
No.	40	45	50	55	60	65	70	75	80	85	90
					Aphidius testaceipes (Cress.)						
1	0	0	0	0	2	8	10	10	5	0	0
2	0	0	0	1	3	10	12	12	5	1	0
3	0	0	0	1	2	12	10	10	6	2	0
4	0	0	1	0	3	9	12	12	2	0	0
5	0	0	0	1	4	7	12	12	5	0	0
6	0	0	0	0	3	10	13	11	4	0	0
7	0	0	1	1	2	8	14	11	3	0	0
8	0	0	0	1	3	9	15	10	5	2	0
9	0	0	0	1	2	11	10	12	3	3	0
10	0	0	0	0	2	10	13	11	6	1	0
					Aphelinus nigritus How.						
1	0	0	2	5	12	13	12	8	0	0	0
2	0	2	3	7	11	12	11	10	1	0	0
3	0	1	2	6	12	14	13	12	4	0	0
4	0	0	3	5	13	14	13	12	4	0	0
5	0	0	4	6	10	13	13	10	3	0	0
6	0	2	2	6	11	15	12	9	1	0	0
7	0	1	3	7	12	14	13	8	2	0	0
8	0	1	2	6	12	14	14	9	1	0	0
9	0	0	2	7	11	15	13	7	2	1	0
10	0	0	3	6	13	13	13	7	3	0	0

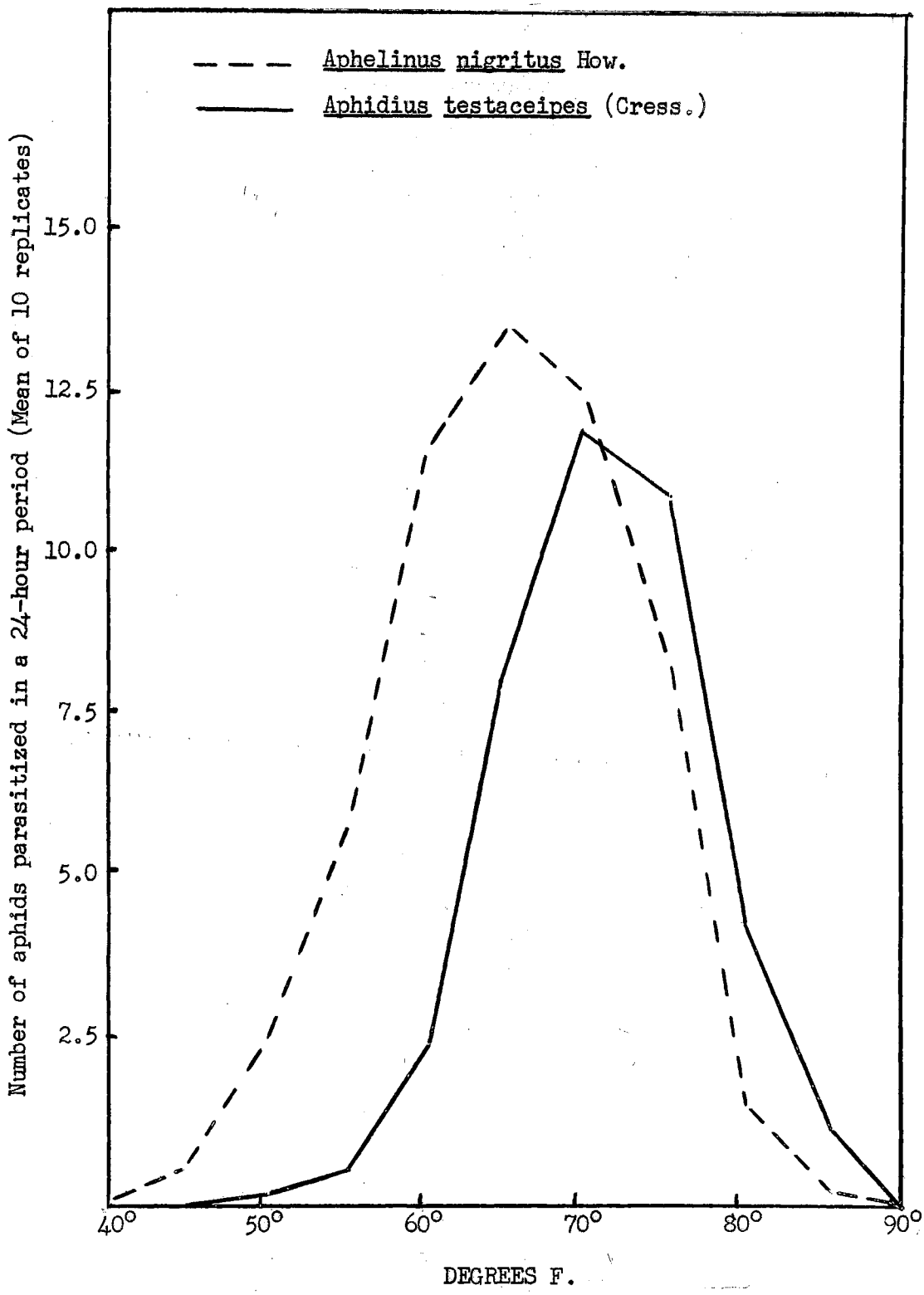

Fig. 2.--Effect of various constant temperatures on the rate of parasitization of Toxoptera graminum (Rond.) by Aphidius testaceipes (Cress.) and Aphelinus nigritus How. for a 24-hour period. Stillwater, Oklahoma. 1960.

there was a rapid decline in parasitization. The parasites could not survive for a 24-hour period at 90° F.

Aphidius testaceipes (Cress.).-- No parasitization occurred at 40 and 45° F., and at these temperatures the parasites were inactive. Very little parasitization was found until 55° F. was reached, and there was a substantial increase in parasitization with each 5-degree increment above this point until the optimum temperature was reached. The highest average parasitization was at 70° F. and there was a rapid decline in parasitization above this temperature. The parasites could not survive for a 24-hour period at 90° F.

An experiment was performed in the greenhouse to determine if Aphidius testaceipes and Aphelinus nigritus could parasitize the first instar nymphs. In an experiment which was replicated 12 times, approximately 30 greenbug adults were caged on each plant for a period of 12 hours. The adults were then removed leaving the young nymphs on the plants, and the minimum number of new-born nymphs was found to be 22 on one plant. In order to maintain uniformity, 20 nymphs were kept for the experiment and the remainder were removed with an aspirator. Three female Aphidius testaceipes were introduced into each of six cages containing plants. In another six cages, three female Aphelinus nigritus were introduced. After a 24-hour period the parasites were removed. Counts of mummies were made after eight days.

No host mummies were found in the cages which contained the parasite A. testaceipes; whereas, in the cages containing A. nigritus, jet black mummies were found mostly within four days. It was observed that many of the host mummies were very small in comparison with those ordinarily found in parasite cultures. Very few of the parasitized nymphs

survived to the fourth instar.

In order to determine if more than one parasite emerges from a single parasitized aphid, 20 parasitized greenbugs were enclosed in individual vials. After a few days parasites emerged. In each case there was but a single parasite per vial.

Interpretation of Results

The results were quite consistent, although there were some small variations in the number of mummies produced. This was largely due to premature death of some of the aphids.

Parasitization of the aphids increased with increased temperatures in both species of parasites up to certain temperatures. The rate of oviposition for Aphidius testaceipes increased up to 70° F. and for Aphelinus nigritus up to 65° F. The largest number of aphids was parasitized by Aphelinus nigritus at 65° F.

Contrasting results on the rate of oviposition by the two parasite species shows that Aphelinus was the most effective parasite at low temperatures, with parasitization occurring at 45° F. These data generally agreed with those of Wood (1958) wherein Aphelinus nigritus parasitized its host at temperatures as low as 42° F. In the case of Aphidius testaceipes there was no parasitization at 45° F. A. nigritus was comparatively a more efficient parasite up to 70° F. Although the optimum for this parasite was 65° F., and there was a decline in parasitization at 70° F., the number parasitized at 70° F. which is optimum for A. testaceipes was greater by comparison. The number parasitized by A. testaceipes was comparatively greater than by the other parasite at higher temperatures. Even at temperatures as high as 80 and 85° F.

there was considerable parasitization by this species. Although A. nigritus oviposited at 85° F., the number of aphids parasitized was small in comparison with the other species.

The fact that Aphelinus nigritus parasitizes practically all stages of its host and is more efficient at low temperatures, suggests that this species should be a better field parasite than Aphidius testaceipes in Oklahoma. However, the disadvantage of this parasite is thought to be its limited host range in comparison with that of the former. This might account for the restricted occurrence of Aphelinus nigritus and for its comparatively poor establishment as a parasite in the field.

SUMMARY AND CONCLUSIONS

The fecundity of the greenhouse strain of greenbug on resistant wheat was very comparable with that of the field strain on susceptible barley; however, the optimum temperature was observed to be higher in the case of the greenhouse strain as compared with the field strain. The greenhouse strain of greenbug appeared to have a very high reproductive potential on the resistant wheat variety at all temperatures as compared with the field strain. There was a lower rate of fecundity by the field strain on resistant Sel. 28-A wheat than on susceptible barley at all temperatures. The optimum temperatures for reproduction were also different on the two host plants, being higher on the susceptible than on the resistant variety. Although reproduction at the lower temperatures was approximately the same, relatively large differences occurred in the higher temperature ranges. Fecundity was retarded relatively more at high, than at low temperatures on the resistant plant as compared with susceptible plants.

A difference in reaction to temperature by biotypes of the greenbug has been demonstrated in these experiments. There may also be possible morphological differences or even differences in reaction to natural factors in the environment. The presence of different degrees of injury to the resistant Sel. 28-A wheat plants by the two biotypes suggests that there are differences in the salivary secretions of these biotypes.

Parasitization of the aphids by both species of parasites increased with temperature increases until their respective optima for reproduction

were reached. Aphelinus nigritus How. was comparatively more efficient than Aphidius testaceipes (Cress.) at low temperatures. Parasitization by A. nigritus began as low as 45° F., and this parasite was comparatively more effective than A. testaceipes at temperatures up to 70° F. At higher temperatures A. testaceipes proved to be more effective, with parasitization occurring up to 85° F.

The parasitization of practically all stages of its host as well as its greater efficiency at low temperatures suggests that A. nigritus should be a more effective parasite than A. testaceipes on wheat in Oklahoma. However, this parasite is rarely found in the field, and its chief disadvantage is thought to be its limited host range. This is particularly true where the host decreases almost to the vanishing point each year as in the case of the greenbug.

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