THE EFFECT OF APPLE GRAIN APHID [*Rhopalosiphum prunifoliae* (Fitch)] AND GREENBUG [*Toxoptera graminum* (Rond.)] INFESTATIONS ON SMALL GRAINS

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THE EFFECT OF APPLE GRAIN APHID [Rhopalosiphum prunifoliae (Fitch)] AND GREENBUG [Toxoptera graminum (Rond.)] INFESTATIONS ON SMALL GRAINS

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PREFACE

Since the organic phosphate insecticide parathion has had successes in controlling greenbug populations on cereal crops, many producers have been turning to this insecticide in attempting to control apple grain aphid populations which may infest these same crops. Whether this means for control is justified on such crops as wheat, barley and oats is a speculative question insofar as a limited amount of study has been attempted on the extent to which apple grain aphids can be implicated in respect to crop injury.

It was with this viewpoint in mind that Dr. R. G. Dahms, Professor of Entomology, Oklahoma A & M College and Regional Coordinator of small grain insect research for the Bureau of Entomology and Plant Quarantine, suggested to me in the fall of 1952, that I attempt to determine the extent of plant injury on cereal crops relative to apple grain aphid infestations. This I have tried to do by comparing injury caused by this aphid with uninfested and greenbug infested plants. I have attempted to bring together a workable knowledge of existing insect-host plant relationships that may be useful in further scientific studies of the apple grain aphid. The study of apple grain aphid-cereal crop relationships may also provide enlightenment concerning factors effecting resistance of these crops to aphid attack.

I wish to express my sincere appreciation to my major advisor, Dr. R. G. Dahms, for his most valuable advice and counsel which helped me in initiating and conducting the experiments. Grateful acknowledgment

is made to Drs. D. E. Howell, Professor of Entomology and Head of the Department of Entomology, Oklahoma A & M College, F. A. Fenton, Professor of Entomology and Head Emeritus of the Department of Entomology, R. M. Chatters, Associate Professor of Botany and Plant Pathology, and A. M. Schlehuber, Professor of Agronomy and Agronomist in Charge of Small Grain Investigations, of my thesis committee for their constructive criticisms on this report; to Drs. R. R. Walton, Associate Professor of Entomology and D. E. Bryan, Assistant Professor of Entomology for their suggestions; to G. A. Bieberdorf, Assistant Professor of Entomology for the pictured illustrations; to D. E. Russell, Student, for graphic reproductions; to E. A. Wood, Jr., Instructor, R. D. Caid, Student, and B. H. Kantack, Graduate Student, for assisting me in project manipulations; to Dr. F. A. Graybill and R. D. Morrison, Assistant Professors of Mathematics for their counsel and assistance which helped me in making the statistical analyses; and, to my nephew, J. L. Ryland who so zealously assisted me in formulating the tables included in this report.

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INTRODUCTION

Rhopalosiphum prunifoliae (Fitch)[1], the apple grain aphid belongs to one of the most important groups of insects, when considered from an economic standpoint. All aphids are injurious to crops in some form, and a species doing little harm may at times become a serious pest. They feed by means of a slender stylet which is thrust into the plant to extract the sap. Since aphids reproduce prolifically, sap sucking by these pests sometimes constitutes a severe drain on the vitality of the plants. Besides the extraction of plant juices, aphids cause other injuries such as malformation, curling, and discoloration of the leaves, stunting, and even death to the plant. They are known vectors of parasitic fungi, bacteria and viruses, which are causal agents of certain plant diseases. An interesting speculation exists as to the extent to which the apple grain aphid is a factor in this plant injury.

Survey of the Literature [*Rhopalosiphum prunifoliae* (Fitch)]

The first report for occurrence of the apple grain aphid in the United States appears to have been published by Fitch (1851) in New York as *Aphis prunifoliae* on apple.[2]

The apple grain aphid is a migratory species with summer forms on grasses and cereal crops. Early writers, who observed its summer forms, placed it under *Aphis avenae* Fabr., as a species injurious to wheat and

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[1] Order *Homoptera*, family *Aphididae*.

[2] Asa. Fitch. Fourth Ann. Rpt. Regents Univ. N. Y. p. 65. 1851.

oats.

It is doubtful that any other species among the aphids has been so completely confused in the literature as has the apple grain aphid. In acknowledging this difficulty Davis (1914) stated that:

> Numerous reports of injury to apple, wheat and oats have been made since its discovery in 1851, but in most instances there seems to have been some confusion in the species, and it is impossible in such cases to determine just which of several species may have been responsible for the damage...consequently these data must be ignored. The same must be said of many references to grain aphids in which the author has either failed to describe the insect or its habits, or has confused two or more species in his descriptions.[1]

Synonyms listed for Aphis avenae Fabr. are Siphocoryne avenae Fabr., Siphonophora avenae of some authors, Aphis mali of some authors, Aphis annuae Oest., and Aphis fitchii Sand.[2]

More recent systematic studies by Baker[3], based on the Fitch types and European material, has placed the species known as Aphis avenae Fabr. under Rhopalosiphum prunifoliae (Fitch).

Life cycle

The apple grain aphid is almost cosmopolitan. The eggs of this species, which are the over-wintering form found on apple and related shrubs, are pale green when first laid, changing to a glossy black with age. They are deposited between the first buds and in crevices of bark, principally on the smaller branches of the lower portions of the trees. When the temperature is favorable in the spring these eggs hatch giving

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[1] J. J. Davis. The oat aphis. U.S.D.A Bul. No. 112. p. 7-8. 1914.

[2] Ibid., p. 1.

[3] A. C. Baker and W. F. Turner. Apple grain aphis. Agr. Res. Jour. 38 (6): p. 311. 1919.

rise to parthenogenetic, viviparous females known as stem mothers. These stem mothers live approximately 38 to 40 days and each produces 50 to 150 of the young spring agamic forms which may or may not be alate. As many as four generations may be produced. The alate agamic form which is called the spring migrant, flies to grasses and cereal crops about the time of petal fall. All of the forms disappear from the apple about this time. The spring migrants which fly to grasses and cereal crops produce from 9 to 20 young on these secondary host plants. The majority of the summer forms are apterous; however, each generation produces some that are of the alate form. These insects locate mainly on the stems and lower portions of the leaves where they continue to reproduce. Many generations are produced throughout the summer. The immature stages of the apterous summer form covers a period of 6 to 12 days, depending upon the temperature. The average reproductive period is about 18 days. Within this time about 28 young are born. The alate summer form requires from 1 1/2 to 2 days longer than the apterous form to complete its nymphal stages, and it then produces an average of 16 young per mother. Summer dispersal is carried on mainly by the alate form. In the fall, apterous vivipara and fall migrants are produced promiscuously, the fall migrants being male and female. These fly back to the apple or other primary host, where mating takes place and the over-wintering eggs are laid.[1]

In the southern states where the temperatures remain higher, the fall migrants may or may not be produced. These summer forms remain on the secondary host reproducing summer forms throughout the winter months.

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[1] Ibid., pp. 311-324.

Description

The winged summer form is predominantly black, the wingless form being mostly olive green, often with a considerable portion of the posterior part of the body a reddish-brown. The coloration of Rhopalosiphum prunifoliae (Fitch) varies with the seasons. Both winged and wingless forms usually have 6-segmented antennae.[1]

In forms studied by the writer at the Oklahoma Agricultural Experiment Station, the distal segment of the antenna appears long and filamentous. The head is equipped with prominent antennal tubercles that project mesially, and these are armed with spines. The cornicles are cylindrical at their bases and at their extremities, but are sometimes slightly swollen in the middle on the alate form. The alate viviparous females are greenish in color with a glossy black head and thorax. Each side of the abdomen is marked with a row of black dots. There is a black dot at the base of each cornicle. The wings are transparent and the appendages are more or less black. Except for the wings, this form becomes entirely black with age. The nymphal stages and the apterous form are the same as described previously.

Rhopalosiphum prunifoliae (Fitch) is controlled somewhat by predaceous insects such as lady-beetles and syrphid flies. Of the lady-beetles, Hippodamia convergens Guér. is the most abundant. Larvae of the fly, Syrphus americana Wd. feed on the apple grain aphid.

The most common parasite of apple grain aphids and of greenbugs is Aphidius testaceipes (Cress.), a small hymenopterous insect. Both the

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[1] R. H. Painter. Aphids or plant lice on Wheat in Kansas. Kansas State College. Dept. Ent. Mimeo. Cir. No. 86. p. 2. 1950.

apple grain aphid and the greenbug develop and multiply at a temperature of 40° F. or above. This aphid parasite is not very active at a temperature below 65° F. Thus mild winters and cool springs, when the temperature fluctuates between 40°and 65° F., permit these two aphid species to multiply uninterrupted by attack from this parasite.

The apple grain aphid has a wide food-plant host range, particularly of the grasses. Table 1 shows the plants listed by Patch to 1938.[1]

Table 1. Food Plants of [Rhopalosiphum prunifoliae(Fitch)] .

GRAMINEAE-Grass family	CYPERACEAE-Sedge family
Agrostis alba-redtop	Carex spp.
Andropogon sorghum-sorghum	
Avenae sativa-oats	LILIACEAE-Lily family
Dactylis glomerata-orchard grass	Allium cepa-onion
Eleusine coracana-millet	
Hordeum vulgare-barley	ROSACEAE-Rose family
Oryza sativa-rice	Crataegus spp.-Hawthorn etc.
Panicum spp.-Proso millet	Cydonia vulgaris-quince
Phleum pratense-timothy	Malus spp.-apple
Poa pratensis-Kentucky blue grass	Prunus spp.-plum
Secale cereale-rye	Pyrus spp.-pear
Setaria italica-German millet	
Triticum aestivum-wheat	COMPOSITAE-Composite family
Zea mays-corn	Helianthus annuus-sunflower

Adams stated that foliage injury and head drop was caused by Rhopalosiphum prunifoliae (Fitch) to wild rice Zizania aquatica upon which it apparently was feeding.[2]

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[1]Edith M. Patch., Food-plant catalogue of the aphids of the world including Phylloxeridae. Maine Agr. Expt. Sta. Bul. 393. Orono. pp. 56, 67, 74, 149, 150, 234. 1938.

[2]Jean Burnham Adams. Aphids on Canadian wild rice. Can. Ent. 77 (10): p. 196. 1945.

The Greenbug [*Toxoptera graminum* (Rond.)]

In many parts of the United States, and particularly in the South, small grains are frequently attacked by an aphid, *Toxoptera graminum* (Rond.), commonly known as the greenbug. The greenbug belongs to the order *Homoptera*, family *Aphididae*, as does the apple grain aphid. Much work has been done in relation to the injury caused to small grains by this insect, and is readily available in the literature. Since the greenbug and the apple grain aphid have much in common as to environmental requirements and life histories, only enough of a description of the greenbug will be given here so that the reader may more readily make a comparison between these two insect species.

The greenbug was introduced into the United States from Europe sometime before 1882. It has been reported from nearly every state. Severe injury to small grains has been caused in various outbreaks in northern Texas, Western Oklahoma, and in some parts of Colorado, Kansas and Nebraska. Damage has been reported from as far north as southern Canada, and as far east as North Carolina. In 1942, a serious outbreak occurred in Texas and Oklahoma with a loss of more than 61 million bushels of grain.[1] A mild winter and a cool, wet spring is favorable to these population build-ups.

Greenbugs appear in the grain fields in the fall after an estivating period thought to be spent on certain grasses. At least 62 species of grasses are known to be host plants of the greenbug. The chief distinguishing characteristic of the adult insect is a singly branched dis-

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[1] R. G. Dahms. *Preventing greenbug outbreaks*. U.S.D.A. L. No. 309. p. 2. 1951.

coidal vein in the front wings, this being twice branched in the other species. This aphid is light green at birth. With age it becomes dark green with a still darker green stripe down the back. In the southern states, they reproduce throughout the year. The wingless forms are all females and 6 to 30 days after hatching give birth to living young. These young develop into both winged and wingless forms. Each female will produce from 50 to 60 young in 20 to 30 days.

Greenbugs can reproduce at temperatures from 40° to 100° F., but do so most rapidly between 55° and 65° F.[1]

Greenbug populations are held in check to some extent by the small hymenopterous insect, Aphidius testaceipes (Cress.). Both the larval and the adult stage of Hippodamia convergens Guér. feed on the greenbug.[2]

Greenbug injury to plants is more evident than that of other grain aphids. This injury results from its feeding which causes a yellowing of the tissue surrounding the points where the stylet is entered for feeding. These yellow spots become confluent when numerous. Wadley (1929)[3] states that a secretion of a chlorophyl-destroying enzyme into the plant cells is the cause of this damage rather than the extraction of plant juices. Chatters and Schlehuber (1951) confirm this contention by stating that:

When saliva from the greenbug is introduced into the parenchyma tissue, the visible effect is one of protoplasmic modification and destruction.

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[1] Dahms, p. 4.

[2] F. A. Fenton. Field Crop Insects. MacMillan. N. Y. pp. 237, 238. 1952.

[3] F. M. Wadley. Observations on the injury caused by Toxoptera graminum Rond. (Homoptera-Aphididae). Ent. Soc. Wash. Proc. 31(7): p. 135.1929.

Large and small globules supplant the homogeneous protoplasm. Also oyster-shell-like bodies form in the cells as they undergo their several changes preceding necrosis. Modifications of cell walls and/or formation of cavities usually results.[1]

Greenbug stylets pierce the plant tissue intercellularly in reaching phloem cells where they extract the plant juices. In more recent unpublished work done at the Oklahoma Agricultural Experiment Station, Chatters (1953)[2] has found that Rhopalosiphum prunifoliae(Fitch) pierce the intervening cells in reaching the phloem tissue.

Greenbugs also are vectors of certain plant viruses as is Rhopalosiphum prunifoliae(Fitch). A widespread and destructive disease called yellow dwarf in the 1951 California barley crop, characterized by a brilliant yellowing of the leaves, was revealed by investigations to be caused by a virus carried by aphids.[3] The apple grain aphid transmits this virus, and since a specific carrier is not required, there is a possibility that the greenbug is capable of transmission.

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[1]R. M. Chatters and A. M. Schlehuber. Mechanics of feeding of the greenbug (Toxoptera graminum Rond.) on Hordeum, Avena, and Triticum. Okla. Agr. Expt. Sta. Tech. Bul. No. T-40. p. 11, 13. 1951.

[2]R. M. Chatters. Unpublished work at the Okla. Agr. Expt. Sta. 1953.

[3]John W. Oswald and Byron R. Houston. U.S.D.A. P.I.S.A.E. Plant Dis. Rptr. 35. p. 471. 1951.

METHODS AND MATERIALS

An effort was made during the winter of 1952-53 to determine by greenhouse studies the injury caused to certain cereal crops by the apple grain aphid. Injury caused by this insect was compared with that caused by greenbugs under the same conditions. The relative damage caused to the plants by these two species was then further measured against control plants. Separate colonies of Rhopalosiphum prunifoliae (Fitch) and Toxoptera graminum (Rond.) were established on caged, potted plants and the resultant damage measured against the unhindered growth of control plants grown under similar conditions, but minus the aphid infestations. The experiment was arranged in a completely randomized fashion so that it might readily lend itself to statistical analyses.

The plant varieties were Pawnee wheat (C.I.[1] 11669), Tenkow barley (C.I. 646), and Wintok oats (C.I. 3424), which are adapted varieties known to be susceptible to both the apple grain aphid and the greenbug. They were grown in soil of which the moisture and mineral content approximated that of a good soil normally found in an area where these crops are grown commercially. The soil used was a medium-fine, clay-loam composition of the Roanoke type. The flower pots used were 6 inches in diameter, and the cages were of a cellulose nitrate composition[2] with 80-mesh muslin screen tops.

The mean greenhouse temperature during these experiments was

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[1] C. I. refers to accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

[2] Manufactured by E. I. DuPont DeNemours & Co. (Inc.), Wilmington 98, Delaware.

70.9° F., with daily averages ranging from 63 to 79° F. Apple grain aphid cultures were acquired from the Agricultural Experiment Station at Manhattan, Kansas, and were subsequently maintained on Pawnee wheat. Greenbugs were obtained from the cultures maintained at the Oklahoma Agricultural Experiment Station, and were also maintained on Pawnee wheat.

Fifteen pots each of Pawnee, Tenkow and Wintok were seeded with fifteen seeds per pot. After 10 days the plants in each pot were thinned to 5, leaving only plants of apparent equal height and vigor. Five pots of each of wheat, barley and oats were then chosen at random to use as uninfested checks, 5 were similarly chosen to be infested with 25-3 to 5 day old apple grain aphid nymphs, and the 5 remaining infested with 25-3 to 5 day old greenbug nymphs.

The infestations were made 14 days after the selected cereal varieties were planted. Five days before the time for infestation adult apple grain aphids were placed on a culture of Pawnee wheat. They were permitted to reproduce for three days and then were removed. The nymphs were permitted to grow for two more days, and then were transferred to the test plants. This same process was repeated in making the greenbug infestations. The height of each plant, including the check plants, was taken when the nymphs were placed on the plants. During the period of infestation the cages were removed from all the pots at weekly intervals and the heights of each plant recorded.

Records were made at two-day intervals of the occurrence of and the amount of the damage to the plant tissue, which was a result of the feeding of the two species of aphids employed in the test. The evaluation method used for this measurement was the same as that used by

entomologists at the Oklahoma Agricultural Experiment Station in measuring greenbug injury to plant tissue. This is a numerical scale ranging from 0 to 5 at whole-number intervals. The 0 represents no injury, 5 is equal to 100 per cent dead tissue and the intervening numbers represent percentages relative to their corresponding positions. The greenbug infestations were removed when the plants were approaching condition 4 of the injury scale so that the aphid populations would not kill the plants. Greenbug infested plants were always first to attain this rating. To keep the control factors equal for all of the experiment, it was necessary to remove an apple grain aphid infested pot and a check pot that were of comparable heights at the time of infestation. These 3 pots were measured for final plant height. They then were treated with a mixture made by adding 1/3 ml of a stock emulsion of 0,0-diethyl-0-ethylmercapto-ethyl thiophosphate to 50 ml of water. This systemic insecticide is manufactured under the trade name of Systox.[1] The stock emulsion of Systox was made up of 300 ml of 32.1 percent active ingredients in 1 gallon of water, or was approximately 2.5 percent. This material was applied to the roots, and protected the plants from both apple grain aphids and greenbugs for approximately 6 weeks. They were treated again after this time so that the plants could be kept for further determinations.

A record was kept of the average number of days required for each variety to reach the numerical rating of 4. This permitted some evaluation of the three cereal crops tested as to their comparable relationship with respect to apple grain aphid and greenbug injury.

Tests were made to find what effect aphid injury had on the ability

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[1]Supplied by Chemagro Corp. N. Y., N. Y.

of the plant to resist freeze damage and to produce tillers. After disinfestation the plants were placed outside of the greenhouse. The outside temperature for the first 2 days averaged approximately 56° F. The third day after the plants were placed outside the temperature dropped to a minimum of 19° F. which persisted for approximately 4 hours. The temperature again rose and remained around its former mean. The plants were left outside for one week, after which they were again returned to the greenhouse.

Tiller counts were taken at 10 and 14 weeks after infestation. A problem was presented by the loss of plants within pots. It is well known that plants of the same variety will differ in their ability to tiller, depending upon competition for light, moisture and plant nutrients. The introduction of error from this source was largely overcome by taking the average number of tillers per pot from all the experiments to arrive at pot averages. The tillers per plant were then taken from hypothetically normal populations.

The above information was further correlated with a rate of reproduction test made on the same varieties. This rate of reproduction test was made primarily so that the apple grain aphid and the greenbug could be compared in relation to conditions of the environment imposed by the control factors. This aided in determining how closely allied these factors were in respect to the optimum conditions required by the two species. This test was used also to determine relative rate of reproduction of the two species as a possibly significant factor in relation to differences in crop damage.

The rate of reproduction test was composed of 5 pots of each of the 3 cereal crops used in the comparison experiment. The conditions

differed in this experiment from the one described previously in that the plants in each pot were thinned to 3 to permit the use of a smaller type cage so that each plant was caged separately. This gave a population of 15 plants for each of the wheat, barley and oat varieties to be infested with apple grain aphid and a like number for greenbug infestation.

No control plants were used in this phase of the work. The plants were measured at the time of infestation which was 14 days after planting. One 24-hour-alate adult aphid was placed on each plant. Newly winged adults were placed on the plants because it permitted the simultaneous placement of equally-aged aphids that had not as yet started to reproduce. These were obtained by placing wingless, nearly-adult aphids on a Pawnee wheat culture 24 hours before the time of infestation.

After seven days the young nymphs were counted and recorded for each of the plants, and it was noted whether or not the winged agamic female was still alive. When the adult was absent, young nymphs were not counted in the final analysis when the plant harbored less than 3. It was felt this would eliminate error from being introduced into the experiment by possible injury of the 24-hour-alate aphid when it was originally introduced into the cage.

After this count was made the small cages were removed and one of the large cages used in the comparison experiment was placed over the plants. The pots were thus maintained until the aphid populations increased sufficiently to cause injury to the plants. Daily ratings of the damage to plant tissue were kept until they approximated condition 3 on the damage rating scale described previously. Although it was

known that plants will sometimes return to normal growth after an injury rating of 4 when the greenbugs are removed, it was thought that plants suffering this degree of injury by the apple grain aphid would not recover. Since the plants were to be kept alive to determine a rate of recovery, it was advisable that the condition 3 be considered the maximum injury permitted for the sake of comparison.

After condition 3 was reached the plants were measured for height, and the number of days of infestation was recorded. They were then treated with Systox as described previously, and a record of the rate of recovery of the plants was maintained. The same scale as used in tissue damage was utilized in a reverse fashion as new growth replaced the damaged tissues.

The plants were kept for further determinations on tillering without being subjected to frost damage. Approximately 10 weeks after planting a tiller count was made. A similar count was made after 14 weeks.

RESULTS

Detailed observations were made on Pawnee wheat, Tenkow barley and Wintok oats to obtain comparative results of the feeding of Rhopalosiphum prunifoliae (Fitch) and Toxoptera graminum (Rond.).

Effects Upon Pawnee Wheat

Rate of reproduction

In the rate of reproduction test on Pawnee wheat the apple grain aphid showed a reproductive capacity ranging from a minimum of 6 nymphs to a maximum of 19 in a 7-day testing period. This gave an average of 12.57 per adult on 14 plants where successful introductions were made. With the greenbug, 15 introductions were successful. The minimum number of nymphs was 3 and the maximum 19 with an average of 12.93. These data indicate a slightly higher reproductive potential for the greenbug than for the apple grain aphid. When analyzed (Table 2), this difference was

Table 2. Analysis of Variance for Rate of Reproduction of Apple Grain Aphid and Greenbug in One Week on Pawnee Wheat.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	19	164.8000	
Treatment	1	5.0000	5.0000
Between Pots in Treatment (Error term)	8	107.8000	13.4750
Between Plants in Treatment	10	52.0000	5.2000

not statistically significant under the conditions of the experiment.

Comparison of damage at 2 weeks

The average height of the plants at the time of infestation varied slightly for the three treatments, the check plants being the highest (see Table 3). The plants infested with Rhopalosiphum prunifoliae (Fitch) grew more than the check plants and much more than those infested with Toxoptera graminum (Rond.) in the first 2 weeks after infestation. Whether this resulted from a stimulating effect produced on the plants by the apple grain aphid, or was merely the result of these plants being smaller at the time of infestation, has not been determined. The apple grain aphid plants were slightly shorter in height when they were infested. This was because of the random method of choosing pots at the time of infestation to facilitate statistical analysis.

Fourteen days after infestation the aphids showed a tremendous population build-up. This was true for both species. At this time many of the aphids showed a tendency toward dispersal by concentrating around the interior perimeter of the chimney-type cages. Whether or not this is a normal tendency that would exist in the field is not known. After 14 days, the apple grain aphid infested plants showed a gradual decrease in plant growth, but did not show the severity of stunting that was found in the greenbug infested pots. As the greenbug infested plants were approaching the numerical rating 4, apple grain aphid infested plants showed only a very slight degree of chlorophyl depletion. Plants infested with the apple grain aphid did not show any visible sign of cellular damage during the first 14 days. When disinfested at 16.4 days, these plants showed a very slight chlorosis in the cellular tissue as compared with 79.20 per-

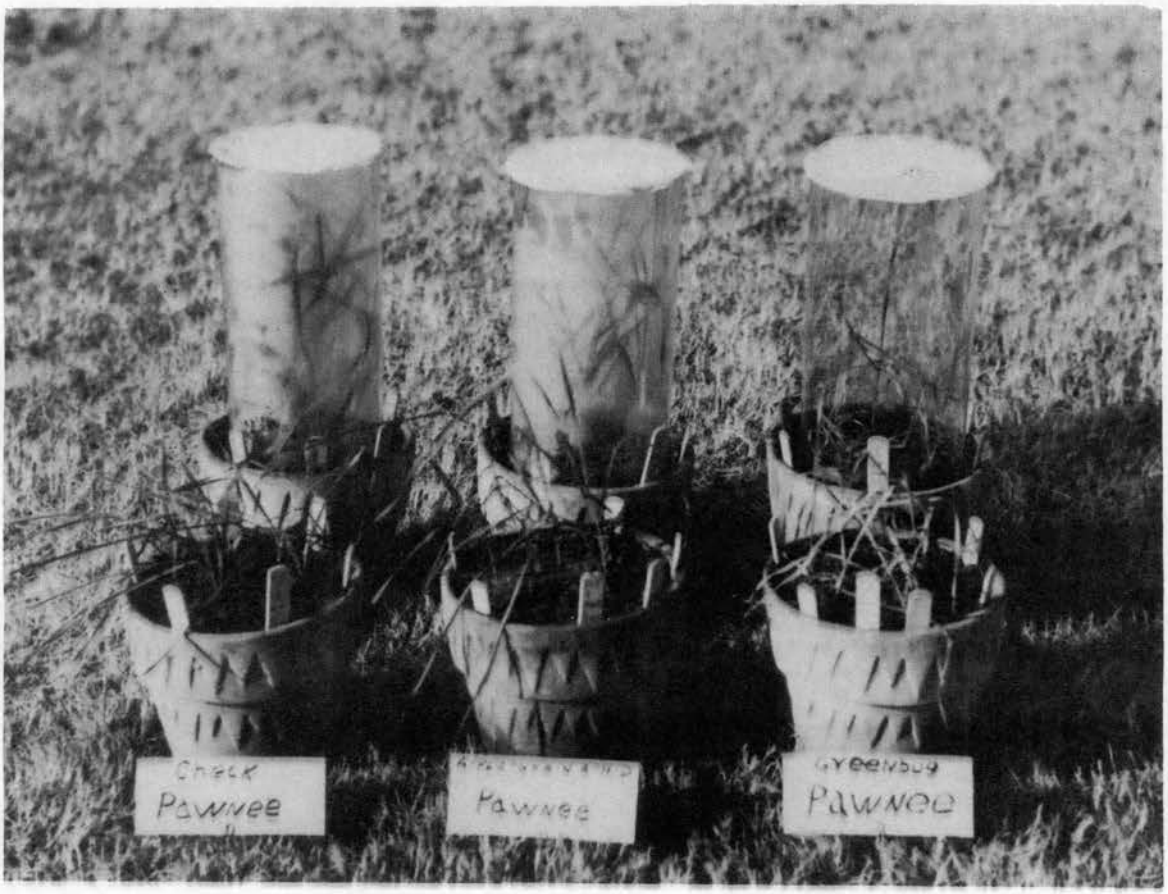

Figure 1. Pawnee Wheat and Aphid Relationship at 2 Weeks. Note the similarity in physical appearance of apple grain aphid infested plants and the check plants. Note also the type of equipment used in the experiment.

cent dead tissue on the greenbug infested plants. When the cages were removed and the plants placed outside of the greenhouse, plants of both of the infestations showed a weakened condition which resulted in an inability of the plant to maintain its erect position. This condition was expressed to a greater extent by plants injured by greenbugs, the apple grain aphid infested plants showing only a minor tendency towards a weakened plant structure.

Table 3. Comparison of Damage Caused to Pawnee Wheat by the Apple Grain Aphid With That of the Greenbug.

Treatment		Average of 25 Plants				
		Height in Inches[1]	Height Increase		Rating	Percent of Dead Tissue
			Inches	Percent		
Check	Initial	7.70			0	0
	At 7 days	9.05	1.35	17.48	0	0
	At 14 days	10.17	2.47	31.99	0	0
	Final	12.42	4.72	61.14	0	0
Apple Grain Aphid	Infestation	7.04			0	0
	At 7 days	8.82	1.78	23.92	0	0
	At 14 days	10.18	3.14	36.82	0	0
	Disinfested	10.78	3.74	39.65	+	+
Green-bug	Infestation	7.23			0	0
	At 7 days	8.52	1.29	16.43	0.04	0.80
	At 14 days	9.06	1.83	25.24	3.48	69.60
	Disinfested	9.21	1.98	27.34	3.96	79.20

+Chlorophyl depletion very slight.
Average number of days infested 16.4.

[1]Height data for statistical analysis taken at 14 days. This material is presented in Table 4.

Statistical analysis on comparative height for the three different treatments on Pawnee wheat failed to show any differences at 2 weeks (see Table 4). This appears largely to be the result of an overlapping of values. These values could be more clearly expressed by eliminating either the greenbug treatment or the check in future experiments.

Table 4. Analysis of Variance for Height of Pawnee Wheat 2 Weeks After Infestation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	74	129.1617	
Treatment	2	20.7217	10.3608
Apple grain aphid vs. Greenbug	(1)	15.6800	15.6800
Check vs. Others	(1)	5.0417	5.0417
Check vs. Apple grain aphid[1]	(1)	0.0013	0.0013
Between Pots in Treatment (Error term)	12	44.8400	3.7366
Between Plants in Treatment	60	63.6000	1.0600

[1]This comparison is not orthogonal to the other two.

Plant reaction to prolonged infestations

A second test conducted to measure plant response to apple grain aphid and greenbug attack that was of apparent equal severity necessitated prolonged infestations by the former of these two aphids. Rhopalosiphum prunifoliae (Fitch) required 14.4 additional days over greenbug to equal a cellular damage rating of 3 of the plant tissue. The tissue damage caused by the apple grain aphid appeared at this time

as a chlorotic effect uniformly distributed over all of the plant tissue. Greenbug damage, in contrast, started in localized spots surrounding the feeding punctures. Later these spots became confluent when numerous. The stunting of the plants by apple grain aphid and greenbug after prolonged infestation bears a comparable relationship to the height experiment at 16.4 days.

The number of days for recovery (shown in Table 5), which was a measure of new plant growth replacing the old, in the case of Toxopotera graminum (Rond.) was equal to the number of days required to cause the damage. The incidence of damage, once it started on plants infested with the apple grain aphid, was similar to that of the greenbug in intensity.

Table 5. Plant Reaction of Pawnee Wheat When Subjected to Comparable Damage by Apple Grain Aphid and Greenbug.

No. of Plants Tested	Height in Inches When		Height Increase	Days Infested	Damage at Disinfestation	No. Days for Recovery	Plant Survival
	Infested	Disinfested					
GB 15	5.60	11.00	5.40	24.0	3.00	24.0	13
AGA 15	5.65	14.02	8.37	38.4	3.07	17.6	12

GB = greenbug
AGA = apple grain aphid

However, it was more permanent, e.g., in more instances it resulted in the death of the plant. In spite of this the rate of recovery of the surviving plants was much more rapid than for those infested with the greenbug. The permanence of aphid injury in either case appears to be a delay in normal growth of the plant. Removal of the aphids resulted in an immediate response in plant recovery.

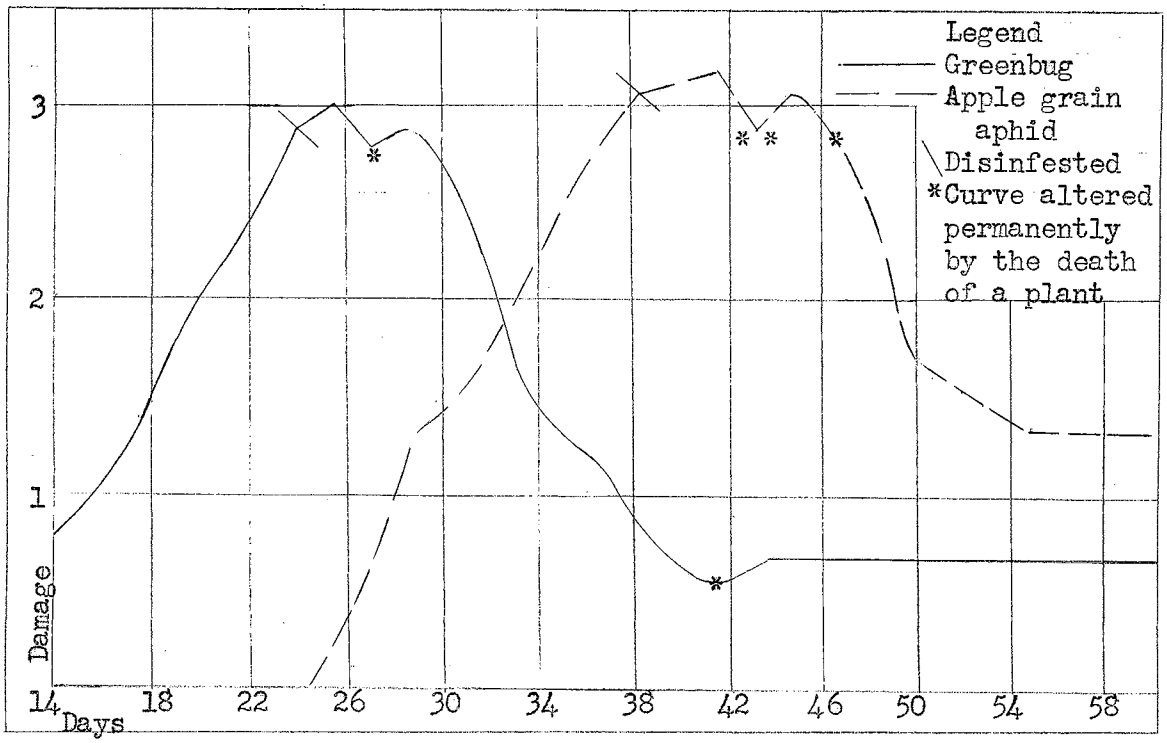

Figure 2. Incidence of Aphid Damage and the Return to Normal of Pawnee Wheat Plants Subjected to Similar Tissue Damage.

Freeze damage after aphid injury

After subjection to a low temperature of 19° F. for 4 hours, 16 percent of the Pawnee check plants were killed. Thirty-six percent of the plants previously infested with apple grain aphids failed to recover. Ninety-six percent of the greenbug infested plants failed to recover. The rate of return to normal growth conditions after freeze damage was very slow when the plants were placed in a warmer environment.

Tillering after aphid injury

Ten weeks after infestation greenbug injury retarded the tillering process much more than injury due to the apple grain aphid (Table 6). Plants which had been injured the most severely were the slowest to show recovery. At 14 weeks the difference in tillering was very slight, indicating that the injury resulted in a retardation of normal plant growth

Table 6. Average Number of Tillers on Pawnee Wheat.

Treatment	At 10 Weeks		At 14 Weeks	
	Per Pot	Per Plant	Per Pot	Per Plant
Check	27.6	6.9	32.5	8.1
Apple grain aphid	25.7	6.4	31.7	7.9
Greenbug	14.9	3.7	31.3	7.8

that was not of a permanent nature.

Effects Upon Tenkow Barley

Rate of reproduction

In the rate of reproduction test on Tenkow barley, the apple grain aphid showed a reproductive capacity ranging from a minimum of 4 nymphs to a maximum of 20 in the 7-day testing period. The average per adult in this case was 11.26 nymphs on each of the 15 plants tested. The minimum number of nymphs produced by greenbugs was 3 and the maximum was 23, with an average of 14.90 on a total of 11 plants. Greenbugs, therefore produced 3.64 more nymphs per parent aphid in 7 days than the apple grain aphid. This difference, however, was not statistically significant (Table 7). Although no records were taken on the daily rate of nymphs produced, newly matured apple grain aphids appeared to lag behind the greenbug 1 1/2 to 2 days in starting to reproduce.

Comparison of damage at 2 weeks

Again, the randomized choice of pots for the three treatments to some extent masked the resultant increase in height (Table 8), of the plants unless analyzed statistically. Plants infested with Rhopalosiphum prunifoliae (Fitch) showed a height increase over those infested

Table 7. Analysis of Variance for Rate of Reproduction of Apple Grain Aphid and Greenbug on Tenkow Barley in One Week

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	19	419.6000	
Treatment	1	72.0000	72.0000
Between Pots in Treatment (Error term)	8	121.6000	15.2000
Between Plants in Treatment	9	226.0000	25.1111

Table 8. Comparison of Damage Caused to Tenkow Barley by the Apple Grain Aphid With That of the Greenbug at 2 Weeks.

Treatment		Average of 25 Plants				
		Height in Inches[1]	Height Increase		Rating	Percent of Dead Tissue
			Inches	Percent		
Check	Initial	5.60			0	0
	At 7 days	8.07	2.47	44.10	0	0
	At 14 days	10.68	5.08	90.71	0	0
	Final	13.64	8.04	143.50	0	0
Apple Grain Aphid	Infestation	5.19			0	0
	At 7 days	7.51	2.32	44.61	0	0
	At 14 days	9.56	4.37	84.03	0	0
	Disinfested	10.70	5.51	107.50	+	+
Greenbug	Infestation	5.08			0	0
	At 7 days	7.22	2.14	42.24	0.08	1.60
	At 14 days	7.73	2.65	51.96	2.88	57.60
	Disinfested	7.91	2.83	55.62	3.84	76.80

+Chlorophyl depletion slight.
Average number of days infested 17.2.

[1]Height data for statistical analysis taken at 14 days. This material is presented in Table 9.

Figure 3. Tenkow Barley and Aphid Relationship at 2 Weeks. Both apple grain aphid and greenbug infested plants have maintained their erect positions.

with Toxoptera graminum (Rond.), but the difference was not so great as in the wheat experiment. The check plants in the case of Tenkow barley outgrew those infested with the apple grain aphid or the greenbug. Population build-up on Tenkow barley after 14 days was similar to that in the wheat experiment with the same general tendency towards dispersal. Plant tissue damage by Rhopalosiphum prunifoliae (Fitch) after 14 days, although greater than for wheat, was still negligible. The barley plants maintained a more rigid structure than did wheat; however, both infested treatments showed an apparent weakening of the plant when compared with the check plants with those infested with greenbug being the most severe.

Analysis of the increase in height at two weeks did not show a significant difference between the check plants and those infested with the apple grain aphid. There was a statistically significant difference between the degree of stunting caused by Rhopalosiphum prunifoliae (Fitch) and that caused by Toxoptera graminum (Rond.), the latter showing the greater severity (Table 9).

Plant reactions to prolonged infestations

When testing Tenkow barley under longer periods of infestations, Rhopalosiphum prunifoliae (Fitch) required 14 more days than Toxoptera graminum (Rond.) to reach a damage rating of 3 (shown in Table 10). External appearances of damage to Tenkow barley by these insects was in all respects similar to that caused to wheat. The apple grain aphid and greenbug infested plants maintained their same relationship in respect to stunting that they showed at 17.2 days.

The number of days required for the plants to recover from greenbug damage was nearly double that for plants infested by the apple grain aphid

Table 9. Analysis of Variance for Height of Tenkow Barley at 2 Weeks After Infestation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Total	74	218.4450		
Treatment	2	111.6800	55.8400	12.49**
Apple grain aphid vs. Greenbug	(1)	42.3200	42.3200	9.46**
Check vs. Others	(1)	69.3640	69.3640	15.51**
Check vs. Apple grain aphid[1]	(1)	15.6800	15.6800	3.51
Between Pots in Treatment (Error term)	12	53.6650	4.4720	
Between Plants in Treatment	60	53.1000	0.8850	

[1]This comparison is not orthogonal to the other two.

**Tabulated F at 5% level = 4.75, tab. F at 1% = 9.33 with df 1 and 12; tab. F at 1% with df 2 and 12 = 6.93.

Table 10. Plant Reaction of Tenkow Barley When Subjected to Comparable Damage by Apple Grain Aphid and Greenbug.

No. of Plants Tested	Height in Inches When		Height Increase	Days Infested	Damage at Disinfestation	No. Days for Recovery	Plant Survival
	Infested	Disinfested					
GB 12	4.60	10.70	6.10	23.2	2.90	32.8	10
AGA 15	4.63	14.80	10.17	37.2	3.07	16.8	13

GB = greenbug
AGA = apple grain aphid

(Table 10). The similarity in the expression of the curves showing damage (Figure 4), did not hold true in the rate of recovery of the plants. This suggests a more permanent type of damage to greenbug infested plants which results in a longer period being required by the plant to again attain its normal growth. The permanence of injury caused by the two aphid species to Tenkow barley appears as it did in wheat to be only an indirect effect which causes delay in normal plant growth.

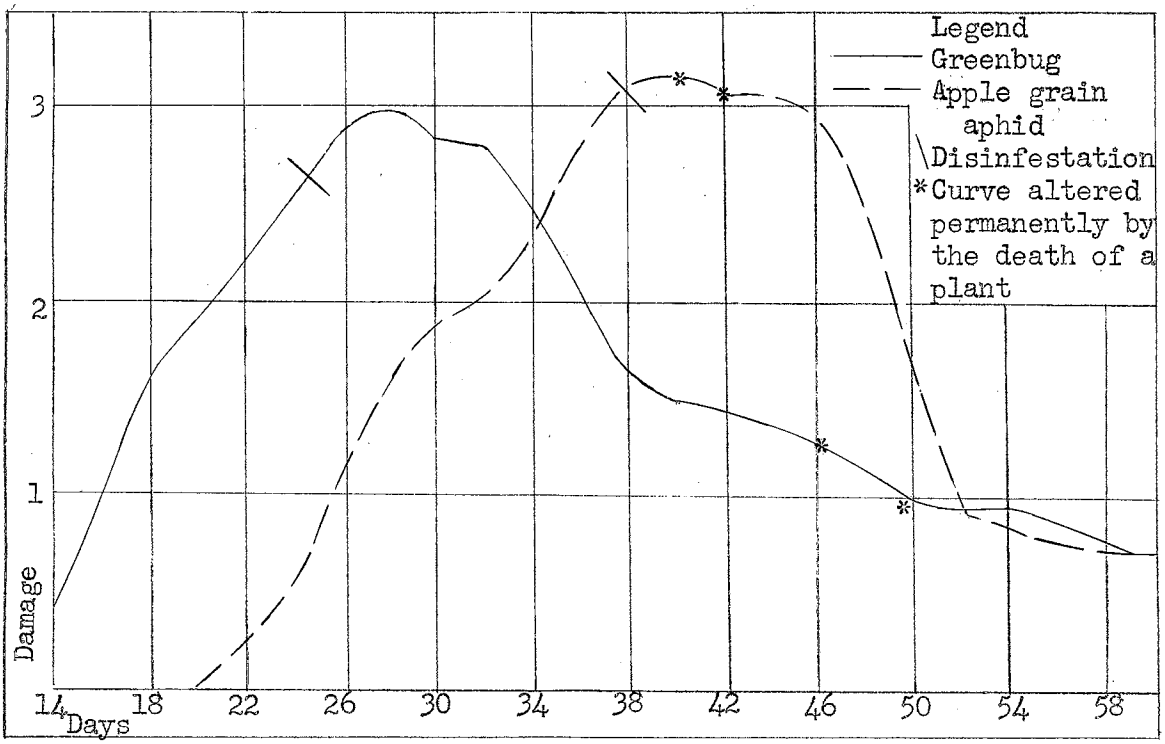

Figure 4. Incidence of Aphid Damage and the Return to Normal of Tenkow Barley With Similar Tissue Damage.

Freeze damage after aphid injury

When Tenkow barley was subjected to a low temperature of 19° F. for 4 hours, the resultant loss was 40 percent of the check plants. Apple grain aphid infested plants survived somewhat better with a 31.58 percent loss. The greenbug infested plants showed a 76 percent loss. The

rate of response to normal growing condition for the plants that survived was good.

Tillering after aphid injury

Tillering after aphid injury on Tenkow barley showed a wide variation at 10 weeks (shown in Table 11). Apple grain aphid infested plants had the most tillers at this time. This variation correlates with the variations in the frost damage experiment, suggesting that the plants that were infested with the apple grain aphids may have withstood low temperature because of some factor related to infestations. Greenbug injured plants showed the smallest number of tillers at 10 weeks. At 14 weeks the differences in tillers per plant was slight.

Table 11. Average Number of Tillers on Tenkow Barley.

Treatment	At 10 Weeks		At 14 Weeks	
	Per Pot	Per Plant	Per Pot	Per Plant
Check	25.5	6.4	49.4	12.3
Apple grain aphid	27.0	6.7	44.7	11.2
Greenbug	18.9	4.7	41.1	11.0

Effects Upon Wintok Oats

Rate of reproduction

The reproductive capacity of Rhopalosiphum prunifoliae (Fitch) feeding on Wintok oats was similar to the results obtained on barley. The minimum number of nymphs produced was 4 and the maximum was 21. The average was 11.87 nymphs reproduced in a 7-day period. The number of

plants tested in this case was 14. This also was the number of successful aphid introductions that were made with Toxoptera graminum (Rond.). The greenbug adults produced from 11 to 23 nymphs. The average for the greenbug in the 7-day testing period was 15.85. This difference of 3.98 nymphs in the rate of reproduction of the two species on oats was not statistically significant (Table 12), under the conditions of this experiment.

Table 12. Analysis of Variance for Rate of Reproduction Test With Apple Grain Aphid and Greenbug on Wintok Oats at One Week.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	19	512.0000	
Treatment	1	64.8000	64.8000
Between Pots in Treatment (Error term)	8	349.2000	43.6500
Between Plants in Treatment	10	98.0000	9.8000

Comparison of damage at 2 weeks

Stunting by both the apple grain aphid and the greenbug was quite marked at 2 weeks on Wintok oats. Both the apple grain aphid and the greenbug caused stunting of Wintok oats that was statistically significant (Table 14). The difference in damage between these two species was too small to be of statistical significance. In respect to tissue damage at disinfestation, the apple grain aphid had noticeably depleted the chlorophyl to what approximated a rating of 1 on the rating scale. Population build-up and aphid reaction on oats were similar to that on wheat and barley. Both of the infested plant treatments exhibited

Figure 5. Wintok Oats and Aphid Relationship at 2 Weeks.
Note the degree of damage inflicted on the plants by both the Apple grain aphid and the greenbug.

Table 13. Comparison of Damage Caused to Wintok Oats by the Apple Grain Aphid With That of the Greenbug.

Treatment		Average of 25 plants				
		Height in Inches[1]	Height Increase		Rating	Percent of Dead Tissue
			Inches	Percent		
Check	Initial	4.63			0	0
	At 7 days	6.14	1.51	32.54	0	0
	At 14 days	8.05	3.42	73.70	0	0
	Final	8.86	4.23	91.95	0	0
Apple Grain Aphid	Infestation	4.72			0	0
	At 7 days	6.29	1.57	33.27	0	0
	At 14 days	6.63	1.91	40.46	0	0
	Disinfested	6.95	2.23	47.24	+	+
Green-bug	Infestation	4.65			0	0
	At 7 days	5.88	1.23	26.50	0.12	2.40
	At 14 days	6.02	1.37	29.52	3.72	74.40
	Disinfested	6.21	1.56	33.83	3.76	75.20

+Chlorophyl depletion comparable to numerical rating 1. Average number of days infested 14.4.

[1]Height data for statistical analysis taken at 14 days. This material is presented in Table 14.

a weakness in the rigidity of the plant structure.

Plant reaction to prolonged infestations

Wintok oats response to apple grain aphid and greenbug attack of equal severity required 13.1 more days for the former to equal that of the greenbug (shown in Table 15). Tissue damage by the apple grain aphids at this time was the same uniformly distributed chlorotic effect observed on wheat and barley. Plants infested with apple grain aphids exhibited a tendency to suddenly wilt and die at this time. Plants that returned to normal did so quite rapidly (Figure 6), when compared with the green-bug infested plants.

Table 14. Analysis of Variance for Height of Wintok Oats at 2 Weeks.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Total	74	128.1250		
Treatment	2	54.2450	27.1225	8.81**
Apple grain aphid vs. Greenbug	(1)	4.6513	4.6513	
Check vs. Others	(1)	49.5937	49.5937	16.10**
Check vs. Apple grain aphid[1]	(1)	25.2090	25.2090	8.18*
Between Pots in Treatment (Error term)	12	36.9550	3.0795	
Between Plants in Treatment	60	36.9250	0.6154	

[1]This comparison is not orthogonal to the other two.

**Tabulated F at 5% level = 4.75, tab. F at 1% = 9.33 with df 1 and 12; tab. F at 1% with df 2 and 12 is 6.93.

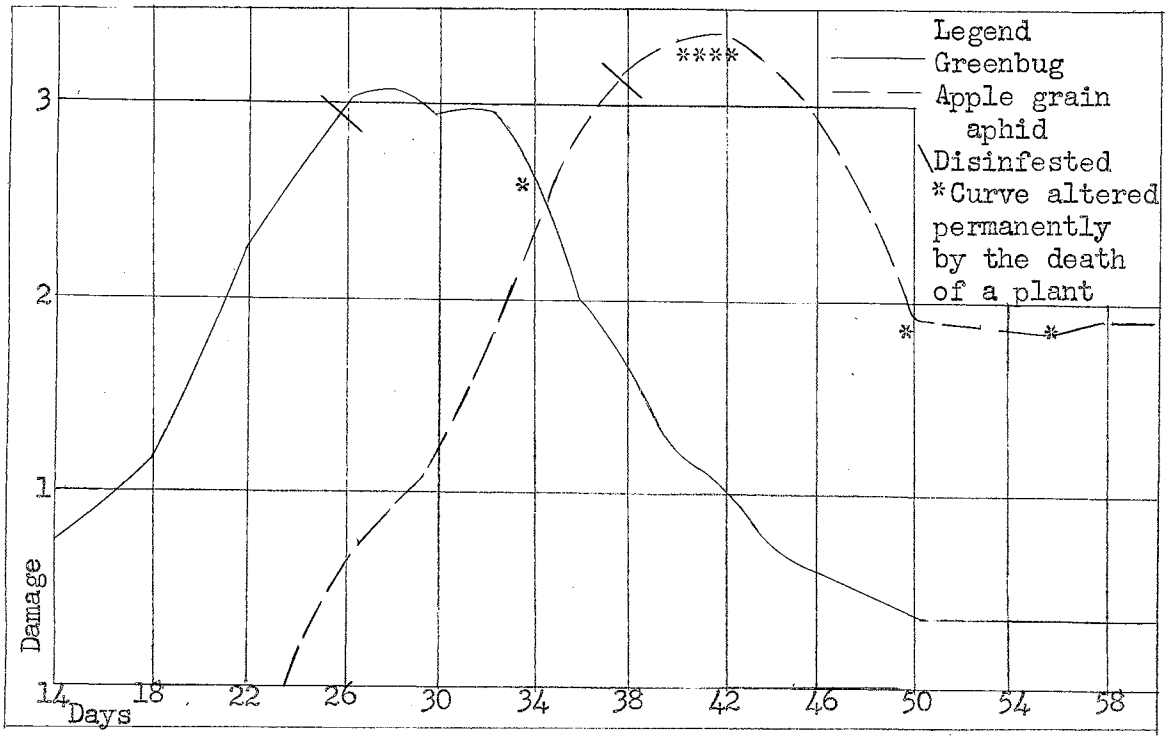

Figure 6. Incidence of Aphid Damage and Return to Normal of Wintok Oats Plants With Comparable Tissue Damage.

Differences in the degree of stunting caused by the two aphid species after the prolonged infestations showed a correlative relationship to the measurement taken at 14 days.

Table 15. Plant Reaction of Wintok Oats When Subjected to Comparable Damage by Apple Grain Aphid and Greenbug.

No. of Plants Tested	Height in Inches When		Height Increase	Days Infested	Damage at Disinfestation	No. Days for Recovery	Plant Survival
	Infested	Disinfested					
GB 14	5.04	10.09	5.05	23.8	3.00	24.2	13
AGA 14	4.89	10.82	5.93	36.9	3.36	19.1	8

GB = greenbug
AGA = apple grain aphid

Freeze damage after aphid injury

A low temperature of 19° F. on Wintok oats resulted in no loss of the check plants. Only 4 percent of the apple grain aphid infested plants were killed, but 56 percent of the greenbug infested plants failed to recover from freeze damage. The return of the remaining plants to normal growth after freeze damage was rapid.

Tillering after aphid injury

Tillering at ten weeks was somewhat less for both plant treatments formerly infested with aphids than it was for the check plants. A marked difference was still shown at 14 weeks at which time the amount of tiller retardation differed but little between apple grain aphid and greenbug affected plants (see Table 16). Since Wintok oats showed a rapid recovery from a low temperature of 19° F., and a fast recovery rate from prolonged infestations, it appears likely that there is some permanent tiller re-

tardation shown here due to injury by both of the aphid species.

Table 16. Average Number of Tillers on Wintok Oats.

Treatment	At 10 Weeks		At 14 Weeks	
	Per Pot	Per Plant	Per Pot	Per Plant
Check	56.1	14.0	68.8	17.2
Apple grain aphid	40.1	10.0	58.1	14.5
Greenbug	32.0	8.0	56.2	14.0

Interaction Between Crops of Wheat, Barley and Oats

Rate of reproduction

In the three tests comprising Pawnee wheat, Tenkow barley and Wintok oats, Toxoptera graminum (Rond.) consistently reproduced more rapidly than Rhopalosiphum prunifoliae (Fitch). Although this difference was too small to be picked up for each crop analyzed separately, combined analysis showed this trend as statistically significant (Table 17). Greenbugs reproduced at a faster rate with the greatest differences being on Wintok oats and Tenkow barley, and with the lowest reproductive rate on Pawnee wheat. Almost conversely, the apple grain aphids reproduced most on Pawnee wheat, and Wintok oats, and least on Tenkow barley. These differences were not statistically significant.

Stunting at 2 weeks

Differences in height between treatments within crops when combined averages were measured statistically were highly significant. Table 18 facilitates the use of the previous tables presented on height data in expressing the differences between the various tests within the crops by

Table 17. Analysis of Variance For Rate of Reproduction Test With the 3 Crops Combined to Show Interaction.

Pawnee Wheat, Tenkow Barley and Wintok Oats				
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Total	58	1102.3333		
Treatment	1	117.6000	117.6000	4.87*
Crops	2	5.7334	2.8667	
Treatment X Crops (Interaction)	2	24.4000	12.2000	
Between Pots in Crops (Error term)	24	578.6000	24.1083	
Between Plants in Crops	29	376.0000	12.9655	

*Tabulated F at 5% level is 4.26, tab. F at 1% is 7.82 with df 1 and 24.

sampling from a large population. The analyses in Table 18 shows no interaction. The greenbug caused the most severe stunting in every case. Difference in the degree of stunting among the several crops was statistically significant. The greatest amount was expressed in Wintok oats. Tenkow barley was next to oats while Pawnee wheat showed the least stunting. This was true for both species of aphid.

Table 18. Analysis of Variance for Stunting at Two Weeks With Crops Combined to Show Interaction.

Pawnee Wheat, Tenkow Barley and Wintok Oats				
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Total	224	838.7156		
Treatment	2	156.5439	78.1719	20.78**
Crops	2	362.9839	181.4969	48.23**
Treatment X Crops (Interaction)	4	30.2028	7.5507	2.00
Between Pots in Crops (Error term)	36	135.4600	3.7627	
Between Plants in Crops	180	153.6250	0.8503	

**Tabulated F at 5% level = 3.26, at 1% level = 5.75, with df 2 and 36.

SUMMARY AND CONCLUSIONS

Since Rhopalosiphum prunifoliae (Fitch), the apple grain aphid, has been of some recent concern because of an apparent tendency towards population build-ups on cereal crops, an attempt was made to study the possible plant injury caused by this insect on Pawnee wheat, Tenkow barley and Wintok oats. These greenbug susceptible varieties were used so that a relative damage estimate could be made of infestations of this aphid when introduced on caged, potted plants in a greenhouse controlled experiment and compared with control plants, and plants similarly infested by the greenbug, Toxoptera graminum (Rond.). The experiments were completely randomized so that they might readily lend themselves to statistical analyses.

Greenhouse temperatures averaged 70.9° F. during the experiments. Infestations were made with 3 to 5 day old nymphs, except in a rate of reproduction test where newly-alate adults were used. Records were made on the relative amounts of plant tissue damage and the degree of stunting caused by both aphid species. 0,0-diethyl-0-ethylmercapto-ethyl thiophosphate was applied to the plant roots for disinfestations. Freeze damage was recorded after 2 weeks of aphid infestation and tiller counts were taken at 10 and 14 weeks.

Results showed that greenbugs had a significantly higher reproductive rate than the apple grain aphid on the three crops in the order of oats, barley and wheat. Apple grain aphids reproduced more abundantly on wheat. The apple grain aphid caused no stunting of Pawnee wheat after 2 weeks of

infestation. Although stunting caused to wheat by the greenbug was apparent, it could not be analyzed statistically because of an overlapping of values. This overlap resulted from using both check and greenbug control measures. Only on Wintok oats did the apple grain aphid show a statistically significant stunting of the plant; whereas, that caused by the greenbug on both barley and oats was highly significant. Plant tissue damage caused by apple grain aphids appeared as a chlorotic effect, very slight on wheat, slight on barley and quite noticeable on oats. Injury symptoms appeared on plants infested with greenbugs much earlier than on those infested with apple grain aphids. Prolonged infestations of apple grain aphids eventually caused a condition of the plant comparable in severity to greenbug injury. This appeared to be caused by a severe sapping of the plant juices. The plants would then die suddenly. This held true for the three crops in varying degrees. It is felt that this condition would not exist in the field, because of the dispersal tendency exhibited earlier by the aphids which would result in reduced populations on the plant. Freeze damage of the plants was not so severe for apple grain aphid infested plants as for those that had been infested with greenbugs. In the case of Tenkow barley there were fewer plants killed by freeze among the apple grain aphid infestations than for the check plants. Tillering of the plants injured by both aphid species was somewhat delayed but there appeared to be very little permanent injury. Wintok oats did show some indication of permanent tiller retardation by both species of aphid.

SELECTED BIBLIOGRAPHY

Adams, Jean Burnham. Aphids on Canadian Wild Rice. Can. Ent. 77(10): p. 196. 1945.

Atkins, I. M., and R. G. Dahms. Reaction of Small Grain Varieties to Greenbug Attack. U. S. Dept. Agr. Tech. Bul. 901. 30 p. 1945.

Baker, A. C., and W. F. Turner. Apple grain aphis. Jour. Agr. Res. 38(6): p. 311-324. 1919.

Chatters, R. M., and A. M. Schlehuber. Mechanics of feeding of the greenbug (Toxoptera graminum Rond.) on Hordeum, Avena, and Triticum. Okla. Agr. Expt. Sta. Tech. Bul. No. T-40. pp. 11, 13. 1951.

Chatters, R. M. Unpublished work on apple grain aphid feeding punctures at the Okla. Agr. Expt. Sta. 1953.

Dahms, R. G. Comparative tolerance of small grains to greenbugs from Oklahoma and Mississippi. Jour. Econ. Ent. 41: 825-826. 1948.

_____. Preventing greenbug outbreaks. U.S.D.A. L.No. 309. pp. 2, 4. 1951.

Dahms, R. G., and F. A. Fenton. Plant breeding and selecting for insect resistance. Jour. Econ. Ent. 32(1): 131-134. 1939.

Davis, J. J. The oat aphis. U.S.D.A. Bul. No. 112. pp. 1, 7, 8. 1914.

Fenton, F. A. The 1939 Greenbug outbreak in Oklahoma. Jour. Econ. Ent. 33(4): 628-634. 1940.

_____. Field Crop Insects. MacMillan. N.Y. pp. 237, 238. 1952.

Fitch, Asa. Fourth Ann. Rpt. Regents. Univ. N.Y. p. 65. 1851.

Oswald, John W., and Bryon R. Houston. U.S.D.A., P.I.S.A.E. Plant Dis. Rpt. 35: p. 471. 1951.

Painter, R. H. Aphids or plant lice on wheat in Kansas. Kansas State College Dept. Ent. Mimeo. Cir. No. 86: p. 2. 1950.

_____. Insect resistance in crop plants. MacMillan. N.Y. 520 pp. 1951.

Patch, Edith M. Food-plant catalogue of the aphids of the world including the Phylloxeridae, Maine Agr. Expt. Sta. Bul. 393. Orono. pp. 56, 67, 74, 149, 150, 234. 1938.

Wadley, F. M. Observations on the injury caused by Toxoptera Graminum (Rond.) (Homoptera-Aphididae) Proc. Ent. Soc. Wash. 31(7): p. 135. 1929.

Walton, R. R. Greenbug injury on barley varieties at Woodward, Oklahoma in 1943. Proc. Okla. Acad. Sci. 24: 38-42. 1944.

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