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GREENBUGS
and Some Other Pests of Small Grains

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SUMMARY

Information is given in this bulletin on the biology, distinguishing characteristics and control of greenbugs, mites and false wireworms, all important pests of small grains in Texas.

The greenbug, probably Mediterranean in origin, has been a pest of small grains in the United States since 1882, with several severe outbreaks occurring since that time. Greenbugs are preyed upon by a number of insect enemies, among which are lady beetles, nabids, lacewing flies and syrphid flies. They also are parasitized by a tiny wasp. Greenbugs can reproduce well at temperatures between 40° and 80° F. whereas most of their insect enemies reproduce slowly at temperatures below 65°. Thus, long periods of cool weather permit the greenbug to increase rapidly.

Cultural practices which will promote the development of vigorous plants are encouraged.

At present, the use of insecticides is the best means of controlling established infestations of greenbugs. Of the many insecticides tested, parathion and methyl parathion were the most profitable. Gamma BHC was effective under ideal weather conditions, but it performed in an erratic manner under less favorable conditions. TEPP also gave good control.

Applications were made when 50 greenbugs per row foot were found on small wheat. If plants were large, spraying began with populations of 100 per foot of drill row. Days with temperatures of at least 50° F. and with winds of less than 10 miles per hour were best for application. In irrigated wheat, treatments made as soon as possible after the water was applied insured the best kill.

Since the use of chemicals against the greenbug is not always dependable and is expensive, it is necessary to seek a more satisfactory control. One of the most promising methods is the development of varieties of small grains that are resistant to this aphid. Research along this line is now being carried on at the Denton and Amarillo stations.

Chemical control against the brown wheat mite, the wheat curl mite and a white mite is not practical. The only importance of the wheat curl mite is that it transmits the virus causing wheat streak-mosaic. Heavy rains greatly reduce brown wheat mite populations and border irrigation has given control for about 3 weeks. Several of the phosphorous compounds have given good control of the winter grain mite. A suitable rotation may be used to lower mite populations. Mites are much more abundant on continuously cropped grain.

False wireworms damage germinating wheat and sorghum. Their greatest injury is caused during dry fall seasons since they usually increase during dry years. Clean culture and accumulated soil moisture associated with summer fallowing reduce injury. Aldrin, dieldrin, heptachlor and lindane applied as seed treatment have given effective control of false wireworms on sorghum.

ACKNOWLEDGMENTS

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Greenbugs and Some Other Pests of Small Grains

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THE GROWTH OF THE SMALL GRAIN INDUSTRY in Texas, and other parts of the grain belt was made possible by improvements in many phases of production. The development of machinery capable of tilling, seeding and harvesting larger acreages enabled farmers to increase greatly the number of seeded acres. In the development and expansion of agricultural crops, man frequently increases his insect problems. Before the settlement of a country, native insects live on wild plants. As new plants are introduced and grown in greater abundance, native pests and those accidentally brought in from foreign countries, finding the plants acceptable food, may multiply rapidly to injurious numbers.

Measures for the control of these pests may be divided into several categories, among which are natural, cultural and chemical control. Whatever the method and its effectiveness, the cost of control should be a deciding factor as to its practical use. It is evident that no financial profit to an individual will be gained by attempting control when the cost is greater than the probable loss would be without the control measure. Before applying a costly control, a farmer should consider his crop potential and prospective returns.

Small grains in Texas are subject to attack from several pests. The most important of these are greenbugs, mites and false wireworms.

Although sorghum is not a small grain, it shares some important insect problems.

GREENBUG

HISTORY AND BIOLOGY

The greenbug, *Toxoptera graminum* (Rond.), is a name reserved for the most important of several kinds of aphids which commonly infest small grains in Texas. This small, green plant louse has caused periodical crop failures.

The greenbug is an unusual pest in many ways. It is generally most abundant in winter and spring, long before most other pests appear. It is small, nearly the same green color as the leaf and to all but the trained observer, its presence goes undetected until yellow or brown spots appear in the field. These spots indicate areas in which the plants have died as a result of greenbug feeding (Figure 4). These aphids are approximately 1/16 inch in length and when full grown have a dark green stripe down the back. Both wingless and winged forms occur (Figure 1). All of the wingless forms, and most of the winged forms, are females and give birth to living young. Most females begin reproduction in 6 to 30 days after birth and continue to produce two or three aphids a day for 20 to 30 days. Many generations may be produced in a year under favorable conditions.

Male greenbugs have not been observed under Texas conditions. Although several eggs have been recovered from greenbug-infested wheat in the greenhouse, they have not hatched, and there is little evidence that eggs are either deposited or hatched under field conditions in Texas. It appears from studies in the field that greenbugs either oversummer as active aphids in the area, or migrate from areas to the north or south. The distribution pattern of greenbugs in the Panhandle in 1953 and 1954 indicated fall migration from the north, while the localized fall infestations in the 1955-56 season strongly suggested local over-summering.

Greenbugs are most likely to become abundant when a cool summer is followed by a mild winter and a late, cool spring. They can reproduce at 40° F., and at a much more rapid rate at temperatures between 55° and 80°. If the temperature goes as low as 0° or as high as 105°, some greenbugs will be killed, although those in the field become "hardened" to extreme temperatures. Winged forms are most numerous in the field during drouth and windy periods. They reproduce less efficiently than wingless forms, but they fly and are readily blown many miles to establish new colonies.

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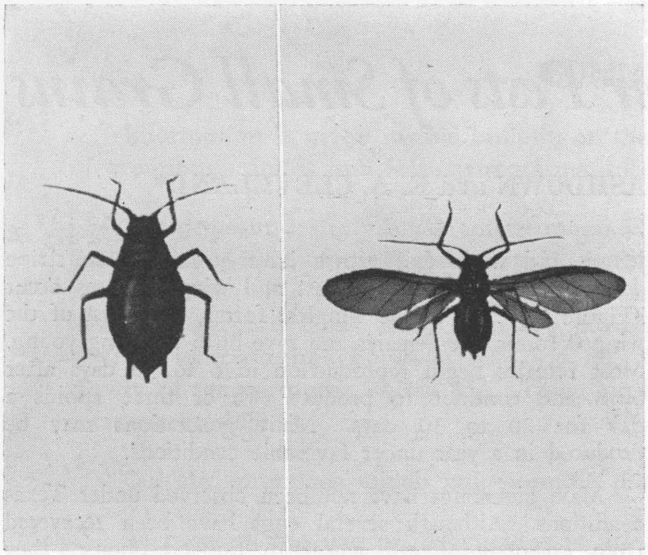

Figure 1. Wingless and winged forms of the greenbug. Courtesy Department of Entomology, University of Kansas.

The greenbug is not new to Texas, or to the rest of the country. It was first described in Italy in 1852 (17) and first recorded in the United States from Virginia in 1882. The earliest recorded outbreak in Texas was reported by J. L. Fooks from Era, Cooke county, on January 26, 1890. A letter by H. K. Jones of Valley View, Texas, dated 1901, indicated that an infestation "about ten years previously killed about all the wheat in the country" (25). This and other correspondence indicate that Collin, Cooke, Denton, Grayson and Wilbarger counties were damaged by this infestation. Another major outbreak occurred in 1901, beginning near Waco and spreading northward into Oklahoma. Another came in 1903, but was again confined to counties in North Central Texas.

A major and very extensive outbreak occurred in 1906-7. This outbreak apparently started in Central Texas and spread northeast to within 60 miles of Chicago, Illinois. By the end of the crop season, it had reached Eastern Colorado, North and South Carolina and Washington, D. C. This was the greatest infestation known from a geographical standpoint, and over 50 million bushels of small grains were destroyed (22).

An outbreak in 1916 covered only North Central Texas counties; major damage occurred in Oklahoma and Kansas (18). Texas was again hit by greenbugs in 1933 in a minor infestation which extended into Oklahoma.

In 1926, an infestation which centered in Minnesota was believed to have originated from migrations of greenbugs which overwintered in Oklahoma and Kansas, although some greenbugs were observed near St. Paul, Minnesota, in 1925. This infestation was somewhat unique in that it centered in Minnesota and extended into Wisconsin, North Dakota, Ohio and Iowa.

Outbreaks in Oklahoma occurred each year from 1934 through 1939. The outbreak of 1939 centered in Northeastern Oklahoma and caused a half-million dollar loss to the small grains crop.

A major outbreak occurred in 1942, involving chiefly small grain acreages in Texas and Southern Oklahoma (2). Almost total crop losses occurred on oats and barley in the principal growing areas, and on wheat in the central area from south of Temple, west to Abilene, east of Dallas and Denton, and extending some distance north of Lawton, Oklahoma. Over 61 million bushels of grain were lost.

Record losses again occurred in 1949-50 and 1950-51. The latter was the most damaging infestation known to have occurred in the Panhandle.

It is obvious that damaging infestations of the greenbug do not occur every year, at regular intervals or in any predictable pattern.

NATURAL CONTROL

Greenbugs are preyed upon by a number of insect enemies, among which are lady beetles, nabids and lacewing flies. They are also parasitized by a tiny wasp. When the temperatures are below 65° F., most greenbug enemies reproduce slowly or hardly at all. Long periods of cool weather thus permit the greenbug to increase in enormous numbers, while its natural enemies increase very slowly. This relationship between the greenbug and its enemies, and the effect of the weather upon them, is partly responsible for greater greenbug abundance during mild winters followed by cool springs.

Predaceous

Chief among the predaceous insects are the lady beetles, Coccinellidae, chiefly *Hippodamia convergens* (Guer.), small, orange, spotted beetles often found in grain fields. These are well known as adults, but the immature, dark slug-like grubs from which the lady beetles develop are not so well recognized. Clusters of orange-yellow eggs, from which these grubs hatch, can be seen attached to the wheat leaves when lady beetles are numerous. Both adults and larvae of these predators feed on the greenbugs and in some years aid materially in controlling them. Much publicity has been given to the sale of these beetles for greenbug control during outbreak years. This practice, however, is not recommended. According to Fenton and Dahms (14), the lady beetle is not an effective control for the greenbug in Oklahoma. "At an average rate of consumption, at favorable temperatures, it would require one gallon of beetles per acre to prevent greenbug increase in a moderately infested field," they reported. Also, if natural conditions were not suitable for lady beetle development at the time of their release, the beetles would, in many cases, disappear from the field. Economically this type of control would be unreasonable.

Included in the greenbug predators are the damsel bugs or nabids, chiefly *Nabis ferus* (Linn.), small, dull gray or brown elongated insects about 5/16 inch in length. These insects search the wheat plants for greenbugs and other aphids, piercing them with their beaks and sucking the blood. They have been found consistently throughout the winter, but always in the adult stage. These predators have been observed moving about and feeding at temperatures below 50° F., at least 10-12° below those at which lady beetles are active. Because they do not begin to multiply until March or April, they constitute a fixed, rather than an expansive, biotic force in reducing greenbug populations. When caged with greenbugs, a single nabid has killed as many as 84 of them in a 24-hour period.

Syrphid flies, *Syrphidae* sp., are classed in the group of greenbug enemies. Medium-size flies, with yellow bands on the body, they are found sometimes hovering around greenbug-infested plants. They dart from place to place with great speed. The larvae or immature stage of these flies feed on the aphids and are found on the plants in the midst of the greenbug colonies. They are slug-like and vary in color from green to brown, gray or mottled. They lack legs and head, but possess pointed jaws, with which they pick and suck all the body contents from a greenbug and discard its empty skin. Syrphid larvae are valuable in aphid colonies since they destroy greenbugs rapidly for considerable periods of time.

In this class of feeders is the immature stage of a delicate, green, gauzy-winged insect called the lacewing fly, *Chrysopa* sp. The larva of this insect is predaceous, crawling about over the plants in search of greenbugs, piercing them with its long jaws and sucking their blood.

Parasitic

Greenbug populations are held in check sometimes by a small wasp, *Aphidius tritici* (Cress), which usually is present when greenbugs are abundant. This wasp deposits its egg within the aphid's body. The egg hatches into a larva so small that it can feed inside the greenbug. When the larva is full grown, the skin of the dead aphid turns brown, remains fastened to a leaf and the wasp passes a resting stage inside. A few days later the adult parasite emerges by cutting a circular lid in the back of the aphid. When the parasite is active, many brown greenbug mummies may be found attached to wheat leaves. These wasps are of less value against the greenbug in the Panhandle than in other areas of Texas.

CULTURAL CONTROL

Most early efforts at control were modifications of cultural practices, such as plowing under volunteer grain, adjustment of planting dates, variety and crop selection. Brush drags, plowing, soil-packing devices and even burning were used without marked success (25).

Greenbug infestations may start in volunteer grain. The exact whereabouts of the insect during the summer is questionable. The aphids appear on the grain in the early fall, possibly migrating by flight into fields of fall-sown grain. Two other oversummering possibilities are from eggs and summer host plants. Greenbug eggs have been observed in the greenhouse during April at the Bushland station (10) but never in the field. Attempts to locate infested plants other than small grain which might maintain the greenbugs in Texas during the summer have been unsuccessful. It is known, however, that the greenbug feeds on a number of grasses, such as orchardgrass, little barley, western wheatgrass, crested wheatgrass and crabgrass. Although there is some evidence that destroying infested volunteer hosts by plowing, fallowing or other cultural measures may help to control greenbugs, data are not sufficiently complete to warrant such recommendations.

Grazing of wheat during greenbug infestations has in some cases decreased greenbug populations considerably.

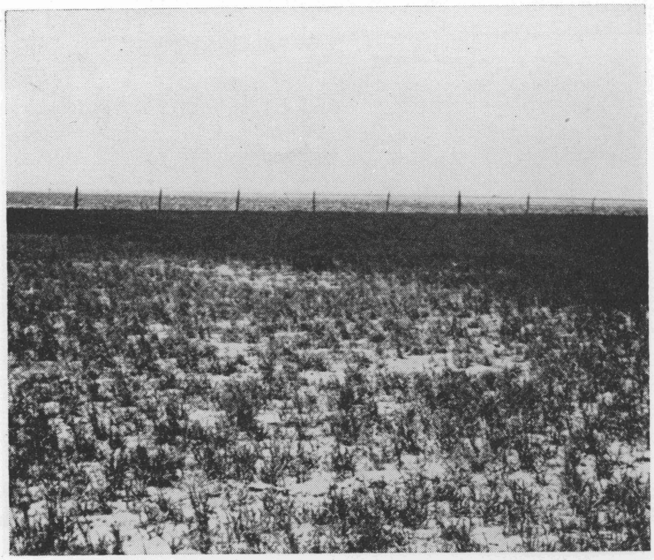

Figure 2. Area in background sprayed with parathion at the rate of 0.5 pound per acre for greenbug control. Unsprayed check in foreground.

However, if grazing is continued in March, grain yields may be reduced in proportion to the lateness of grazing and the earliness of the wheat variety. Usually where small grain fields are heavily infested over an area or a general outbreak is occurring, greenbug populations will increase in a grazed field after removal of the livestock. In such cases, chemical control may become necessary a few days after the cattle are removed. However, if the weather is warm and a good predator population is present, insecticidal application may be unnecessary.

Cultural measures that will stimulate the growth of small grain plants and keep them in a vigorous condition will, in many cases, enable them to withstand more greenbug damage than unhealthy plants. Greenhouse studies conducted at the Amarillo station indicated that wheat grown in soil following alfalfa was more tolerant to greenbugs and supported greater populations than wheat grown in soil following wheat (11). These results were associated with high nitrogen levels in the soil and increased plant vigor (Figure 5).

Large plants frequently survive high infestations of greenbugs while smaller plants are killed. An infestation of 500 greenbugs per linear foot of drill row in small wheat may be more severe than a population of 1,500 per linear foot in large wheat. The smaller wheat would no doubt have more insects per gram of foliage. Foliage clippings were taken along with greenbug counts for a comparison of infestation between two fields in the Dimmitt area under different cropping practices during March 1956. The plots in the fields were 1/20 acre and

TABLE 1. EFFECTS OF CROPPING PRACTICES ON PLANT DEVELOPMENT AND ON GREENBUG INFESTATION IN WHEAT, DIMMITT, 1956

Field	Height of plants, inches	Foliage weight, grams	Number of greenbugs per foot	Greenbugs per gram of foliage
Summer fallowed	6-8	31	1,572	51
Continuously cropped	3-4	7	620	89

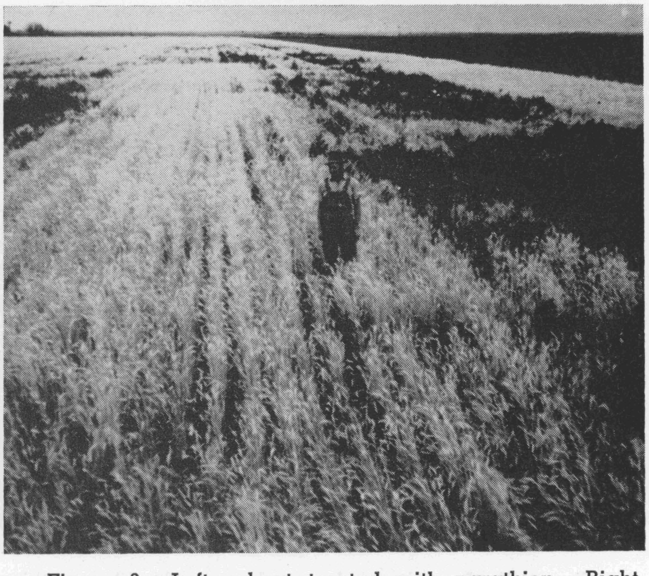

Figure 3. Left, wheat treated with parathion. Right, wheat treated with BHC. Middle, check plot where weeds replaced wheat "killed out" by the greenbug.

the sampling unit was 1 foot of drill row. The results are shown in Table 1.

INSECTICIDAL CONTROL

Apparently the first chemical control was obtained with kerosene emulsions at 8 to 10 percent strength. Whale oil soap solutions also gave excellent control of greenbugs in bluegrass lawns in Washington, D. C., in 1907 (25).

No chemical materials for economic greenbug control were found until new organic insecticides became available following World War II. Severe greenbug outbreaks in 1950 and 1951 afforded an opportunity to develop satisfactory chemical control measures.

Dahms conducted extensive insecticidal tests in 1950. From this work, a very acceptable control program developed, and over 2½ million acres of small grains were sprayed, chiefly with parathion (1). Parathion at .2 to .3 pound per acre was superior to BHC, lindane, DDT or TEPP, and emulsifiable concentrates were the most satisfactory formulations for use in sprays with either air or ground application (8).

Owen *et al.* in 1950 and 1951 (19, 20) found that parathion spray at .3 to .5 pound per acre gave effective control. Gamma BHC dust at .5 to .6 pound per acre gave good control, but sprays were much less effective. Laboratory and field tests conducted by Hanna *et al.* (15) indicated that parathion was more toxic to greenbugs than BHC. They pointed out the necessity for warm temperatures at application time, and found that greenbugs on the leaves of the plants were more readily eliminated by insecticides than those among dead leaves at the base.

Experiments for chemical control of greenbugs have been conducted on the High Plains since 1950. Several insecticides, mainly phosphorus compounds, were tested against the greenbug both in 1955 and 1956 (Table 2). Experiments I and II were conducted at Hereford, the applications being made April 14, 1955. Experiment I consisted of five treatments replicated four times. Each plot was 1/10 acre in size. Yields were increased signifi-

TABLE 2. GREENBUG REDUCTION AND WHEAT YIELDS FOLLOWING INSECTICIDAL TREATMENTS IN IRRIGATED PLOTS AT HEREFORD AND DIMMITT, 1955-56

Treatment	Pounds per acre	Greenbugs per foot of drill row, initial count	Net percent mortality, indicated days after application						Yield, bushels per acre
			2	4	8	14	28	36	
				EXPERIMENT I					
Malathion	1.1	210	—	86	70	—	—	—	14.1
Parathion	.3	186	—	86	82	—	—	—	15.5
Methyl parathion	.3	158	—	90	76	—	—	—	15.8
Demeton	.3	177	—	93	77	—	—	—	14.5
Meta-Systox	.3	229	—	91	76	—	—	—	15.9
Check	—	208	—	196[1]	71[1]	—	—	—	10.9
Difference in yield required for significance									3.6
				EXPERIMENT II					
Thimet (Am. Cyanamid 3911)	.6	75	—	85	90	—	—	—	21.1
Am. Cyanamid 12008	.6	102	—	63	69	—	—	—	20.2
Guthion (Bayer 17147)	.6	167	—	38	56	—	—	—	18.6
Parathion	.6	120	—	92	96	—	—	—	23.0
Check	—	147	—	147[1]	82[1]	—	—	—	16.3
Difference in yield required for significance									3.8
				EXPERIMENT III					
Parathion	.5	1,300	77	—	94	94	97	97	24.1
Methyl parathion	.5	1,235	68	—	93	94	98	92	26.1
Demeton	.5	1,212	85	—	95	93	97	95	28.5
Check	—	980	956[1]	—	1,636[1]	1,786[1]	1,118[1]	385[1]	12.9
				EXPERIMENT IV					
Gamma BHC	.5	540	96	—	91	—	—	—	—
TEPP	.6	530	87	—	77	—	—	—	—
Parathion	.5	520	99	—	93	—	—	—	—
Check	—	628	540[1]	—	83[1]	—	—	—	—

[1]Number of greenbugs per foot of drill row.

cantly by all materials except malathion. In experiment II, the plot size was 1/40 acre and there were four replicates. Yields were increased significantly by parathion and the experimental materials, Am. Cyanamid 3911 and Am. Cyanamid 12008. The chemical 3911 was a little better than 12008, but parathion was superior to both at the same dosage level. Experiment III was conducted at Dimmitt. It consisted of three treatments replicated four times. The plot size was 1/20 acre. Spraying was done on March 28, 1956, when the temperature was 58° F. The application of parathion, methyl parathion or demeton greatly increased the yield. The greatest increase resulted from the application of demeton. Experiment IV, also conducted at Dimmitt, consisted of three treatments replicated four times. Each plot was 1/20 acre in size. Spraying was done on April 25, when the temperature was 80° F. While yield data were not obtained, parathion gave better control than gamma BHC or TEPP.

The results of spraying for greenbug control with parathion are shown in Figure 2.

Additional tests with insecticides were made, usually in single plots, at several other locations in the Panhandle. Results of these experiments are presented in Table 3.

Experiment I consisted of four treatments on dryland wheat, with each plot 1/100 acre in size. Applications were made with a ground sprayer when the temperature was 29° F. Within 8 hours, the temperature rose to 60°. In experiment II, the spray was applied with power equipment that delivered 12 gallons of liquid per acre. The temperature was 53° and the wind velocities 10 to 20 mph. Each plot was 40 feet in width and duplicated. The wheat on the check plots died and was replaced mostly by weed growth (Figure 3). Yields were calculated from samples harvested at random within each plot.

Experiment III was with a series of organic phosphorus compounds. Materials were applied in 40-foot swaths with a Cub airplane when the air was calm or nearly so and the temperature was 74° F. The wheat had been

TABLE 3. AVERAGE PERCENTAGE GREENBUG REDUCTION FOLLOWING INSECTICIDAL TREATMENTS IN SEVERAL PANHANDLE LOCATIONS

Experiment	Location	Date	Number of greenbugs per foot of drill row, initial count	Insecticide	Pounds per acre	Percent reduction after		Yield, bushels of wheat per acre
				GROUND SPRAYER		2 days	10 days	
I	Gruver	1-6-53	12	Parathion	.5	80	100	
				Demeton	.5	95	100	
				Metacide	.5	95	100	
				Chlorthion	.5	100	100	
				Check		33	55	
						5 days	28 days	
II	Hereford	4-4-55	250	Parathion	.5	97	96	19.8
				Metacide	.5	98	96	23.1
				Malathion	.75	93	91	16.0
				Check	—	25	—	0.3
				AIRPLANE		6 days	23 days	
III	Hereford	4-28-54	400	Chlorthion spray	.5	97	99	
				Demeton	.5	83	98	
				Methyl parathion	.5	99	99	
				Malathion	.5	97	98	
				Metacide	.5	99	95	
				Parathion	.5	98	98	
				Check	—	65	79	
						6 days	23 days	
IV	Hereford	4-28-54	85	Parathion spray	.25	87	92	
				Parathion	.5	96	95	
				Check	—	40	79	
						2 days	10 days	
V	Summerfield	4-22-56	250	Parathion dust	.5	—	—	38.5
				Check	—	—	—	28.0
						4 days		
VI	Hereford	4-24-56	300	Parathion dust	.5	97	—	49.8
				Check	—	75	—	44.5
VII	Black	—	350	Gamma BHC dust	1.25	—	—	33.6
				Check	—	—	—	19.2
VIII	Hereford	—	275	Gamma BHC dust	1.0	—	—	37.4
				Methyl parathion spray	.5	—	—	34.3
IX	Black	—	400	Gamma BHC spray	1.25	—	—	70.0
						5 days	20 days	
X	Hereford	4-16-56	250	Metacide spray	.5	70	62	15.0
		4-27-56		BHC spray	1.25	—	—	—

Figure 4. "Greenbug spot" in barley showing discoloration caused by greenbug feeding.

heavily grazed, was irrigated and in the boot stage. Plot size was 2 acres. Experiment IV compared two rates of parathion applied to dryland wheat the same day under ideal conditions. Plots were 10 acres in size and showed considerable greenbug damage before spray application. Experiment V evaluated the effectiveness in terms of increased yield of late airplane applications of parathion dust to wheat in the boot to early-head stage. Half the field was left untreated as a check. The wheat was irrigated just before spraying. Experiment VI was similar to experiment V with the wheat in a less advanced stage.

Figure 5. Wheat plants fertilized at the rate of 60 pounds of nitrogen per acre (left) and plants receiving no nitrogen (right) after 5 weeks of greenbug infestation. USDA Southwestern Great Plains Field Station, 1955.

The results of experiment VII indicated on the basis of yields, that BHC dust is effective under certain conditions for greenbug control.

Tests VII, IX and X were conducted to evaluate certain chemicals for the control of greenbugs on a sizable acreage under practical field conditions. Test VIII compared BHC dust with a methyl parathion spray. The plots were sprayed when the wheat was in the pre-boot stage. Good control was obtained with both compounds. The results of test IX indicate the high yield which can result when an application is applied properly under ideal conditions. In test X, the conditions during applications were unfavorable, resulting in poor control and low yields.

Results of the experiments reported herein indicate that parathion or methyl parathion were effective at the rate of .25 to .5 pound of the insecticide per acre. In North Central Texas, .25 pound per acre usually gave effective control. However, in the Panhandle, .5 pound per acre was needed unless spray conditions were exceptionally good. Application of gamma BHC dust at a rate of .5 to 1.25 pounds per acre or TEPP at .6 pound per acre in a spray also gave good control. Chlorthion and malathion, although safer to use, were not as effective as parathion or methyl parathion for greenbug control.

Good control was obtained when the insecticides were applied with ground equipment or by airplane. Sprays were most effective when the air was calm. During the spring in the Panhandle, high wind velocities are so constant that it is difficult to select a day suitable for spraying.

Factors to be considered in determining whether insecticidal treatment of small grains for greenbug control will be practical are:

Temperatures	Parathion or methyl parathion most effective at temperatures of 50° F. or above at time of application and for 3 hours thereafter. TEPP and BHC effective only when temperatures are above 75°.
Wind velocities	0 to 10 mph for airplane application. Ground equipment up to 15 mph. Higher dosage needed when windy.
Time of year	Low infestations more critical in fall, winter and early spring when plants are small.
Soil moisture potential (dryland)	Do not spray if soil moisture potential and outlook are not adequate to produce 10 bushels per acre.
Size of wheat plants	Critical damage caused by small numbers of aphids on emerging plants. Tillered plants tolerate more greenbugs than younger plants.
Irrigation	If possible, irrigate immediately before spraying.

Number of greenbugs per foot	Treatment justified if there are 50 per foot on small plants or early in season, at least 100 per foot on large plants.
Predators and parasites	If predators and parasites combined equal 1/10 to 1/25 the number of greenbugs, delay spraying.

PRECAUTIONS

Insecticides are poisonous. Handle them with care. Follow the directions and heed all precautions on the container label.

Parathion and methyl parathion are extremely poisonous. They should be applied only by a person thoroughly familiar with their hazards who will assume full responsibility for safe use and comply with all the precautions on the label.

In applying insecticides, try to keep them off your skin and away from your eyes, nose and mouth. When you have finished the job, wash all exposed surfaces of the body with soap and water. Change your clothing.

Do not pasture animals in grain fields for 2 weeks after the fields have been treated with parathion, methyl parathion or Chlorthion. Do not pasture animals in fields treated with malathion for 7 days after application. Small grains treated with TEPP should not be grazed for 3 days after application. If BHC is applied, do not feed the treated crop to dairy animals or animals being furnished for slaughter. BHC should not be used for greenbug control in areas where vegetable crops will follow in the rotation, since residues in the soil may cause off-flavor.

RESISTANCE

Controls that have been developed for the greenbug are not always practical. In areas where yields are low because of low fertility, drouth or winter-killing, costs of insecticidal control may be too high. Most of the available insecticides are ineffective at temperatures below 50° F., when greenbugs are feeding and reproducing. Control by parasites or predators or by cultural means is not dependable. Consequently, new methods of control must be sought. The development of greenbug-resistant small grain varieties offers a promising approach.

Differences in response of plant varieties to insect attack have been recorded for over 100 years. About 100 plant species have shown resistance to more than 100 insects (21). Resistance to aphids in plants has been reported more frequently than that to any other insect group. Wadley (23) was one of the first to observe differences in response of plants to the greenbug. He found it more difficult to rear greenbugs on Mindum durum than on several common winter wheat varieties. He reported that on Vernal emmer less than 10 percent of the aphids matured and that no second generation developed. Fenton and Fisher (13) noticed differences in susceptibility to attack among oat varieties. Walton (24) observed a difference in the reaction of barley varieties to greenbug attack. The reaction of several hundred varieties of wheat, oats and barley under field conditions in Texas and

Figure 6. Reaction of barley varieties to greenbug attack. From left to right in order of increasing resistance are Cordova, Ward, Reno, Kearney and Dicktoo.

Oklahoma was studied by Atkins and Dahms (2). They reported resistance in some wheat and barley strains, but none in oats. Dahms, Johnston, Schlehuber and Wood (9) reported on the reaction of several hundred varieties and hybrids of small grains which were tested for resistance under greenhouse, field and insectary conditions. Many of the barley varieties showed a high degree of resistance, and it was indicated that the resistance was inherited. One variety that occurred as a mixture in *Triticum durum,* Dickinson No. 485, C. I. 3707, showed a high degree of resistance and several others were more resistant than those commonly grown in the hard red winter wheat area. None of the oat varieties showed marked resistance although some variation was observed. Chatters and Schlehuber (7) studied the feeding habits of the greenbug on small grains. They concluded that discoloration and tissue breakdown are caused by the injection into the plant of toxic saliva by the aphid, and that resistance and susceptibility are expressions of physiological differences.

Studies on the resistance of small grains to the greenbug in Texas were initiated at Denton and Bushland in

Figure 7. Summer-fallowed wheat (left) and continuous wheat (right) under drouth conditions. Fallowed wheat had 15 to 40 brown wheat mites per foot of row, while the continuous wheat had 360 to 480 mites. USDA Southwestern Great Plains Field Station, 1953.

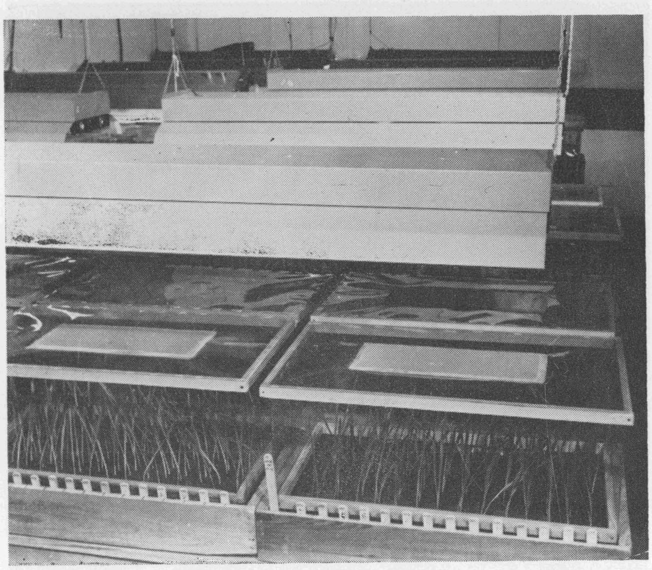

Figure 8. Small grains being tested for greenbug resistance in the insectary, Denton Experiment Station.

1952. These involve insectary, greenhouse and field tests. Differences in susceptibility to greenbug attack among small grain varieties can be shown under each condition. Figure 6 shows differences in reactions of barley varieties at the Bushland station. Plants 3 to 4 inches tall were subjected to uniform greenbug infestation for 5 weeks. In the insectary and greenhouse at Denton, varieties from the world collection of small grain maintained by the U. S. Department of Agriculture and local varieties and strains of small grains are tested for greenbug resistance by exposing them to uniform infestations (Figure 8). They then are rated for their reaction to greenbugs, the ratings being based on the percentage of total leaf area damaged. Those that have a high degree of resistance are referred to the plant breeder for crossing with adapted varieties or strains in an attempt to produce a well adapted, good quality, highly resistant variety. Selections of each of the field-planted generations of the crosses are again tested for resistance in the insectary. Only those which are as resistant or more so than the resistant parent are saved for further development. Varieties and hybrids which have shown resistance under insectary or greenhouse testing are planted in greenbug nurseries in the field at several locations to study their reaction to natural greenbug infestations. Since the initiation of these studies, it has been possible to supply plant breeders with definitely resistant parents, whereas, previously, little was known regarding the reaction of the parents in the crosses.

To date, 7,688 varieties of wheat, oats and barley have been tested for resistance at Denton.

No outstanding resistance was found among 332 domestic and Oriental wheat varieties tested. Some 350 third-generation lines of three wheat crosses involving Dickinson Selection, the most resistant wheat observed to date, have been tested. Many of the selections in each cross show considerably more resistance than the common wheats; therefore, the resistance of Dickinson Selection has been transferred by cross breeding.

A total of 2,609 barley varieties and hybrids have been tested for resistance. These include 115 miscellaneous varieties among which Omugi and Kearney are the most resistant. Plant breeders are having success in concentrating resistance in new lines.

A total of 5,100 oat varieties have been tested. Little resistance was found among 102 domestic varieties, Andrew showing the most, but the degree of resistance is not high. Among the 4,998 oat varieties tested from the collection, only 77 are 10 percent or more resistant than Andrew, the resistant check. Only 7 are 20 percent or more resistant than Andrew. The most resistant variety is Russian No. 77 from Canada. It shows 33 percent more resistance than Andrew. Many of the more resistant oat varieties are from the Mediterranean countries, especially Turkey and Yugoslavia, and this area may serve as a source of further resistance in oats.

Progress has been made by the entomologist and plant breeder in the development of small grain varieties which are resistant to the greenbug. However, until they become available for farmers' use, current chemical control recommendations should be followed.

MITES

BROWN WHEAT MITE

The brown wheat mite, *Petrobia latens* (Müll.), is a pest of small grains. Damage by this mite occurs only during dry weather and in some respects resembles that caused by drouth. A mottling of leaves occurs, and when observed from a distance, a yellowing or bronzing effect may be noted. Infested leaves first show a silvery cast and later turn brown. When this stage is reached, hundreds of mites can be seen on the leaves and on the ground at the base of the plants. The mite has a rounded, metallic dark brown or blackish body about the size of a period in newsprint, with short hairs on the back. The legs are pale yellow, with the fore legs characteristically longer than the other three pairs. It can be identified with a hand lens in the field (Figure 9). This species does not spin webs as do some spider mites.

Brown wheat mites pass the summer as small, shiny, white eggs. The egg is coated with a white waxy material, and one end is flattened in a circular cap somewhat larger than the egg itself. Large numbers of these eggs may be found at the base of the plants in the soil, attached to debris and clods. To hatch, the eggs must be in contact with free moisture. Hatching begins in the fall as soon as there is a small amount of free moisture. Young mites are bright red and have three pairs of legs, but as soon as they feed, most of them become brownish. The next

TABLE 4. EFFECT OF BORDER IRRIGATION ON BROWN WHEAT MITE POPULATIONS, BUSHLAND STATION, 1955

Date	Average number of mites per foot of row: Irrigated April 23	Average number of mites per foot of row: Irrigated March 23 and April 23	Percent mortality
March 30	113	6	95
April 6	147	12	92
April 21	164	51	69
April 29	10	11	0

two stages each have four pairs of legs; some of them have greenish bodies and some resemble the adults in color. After hatching, the mites reach the adult stage in 9 to 10 days. Egg laying begins 1 or 2 days later. Winter eggs, laid during the fall, winter and early spring, are brick red and spherical. They hatch in 6 or 7 days under favorable conditions. Each adult lays 70 to 90 eggs in a 3-week period. According to Baker and Pritchard (3), males are unknown and the eggs hatch without fertilization. During the late spring, certain adults begin to lay summer eggs, and will lay about 30 during a 3-week period. An adult does not produce both summer and winter eggs.

Heavy rains reduce greatly the brown wheat mite populations. Replicated plot experiments at the Amarillo station have shown that irrigation lowers populations. The effect of border irrigation on the brown wheat mite is shown in Table 4. Border irrigation is similar to flooding from field ditches, except that small levees or border dikes confine the water to a limited area as it moves across the field. Although mite populations were low, control with border irrigation was good for about 3 weeks. On April 23, after flooding of the plots (irrigated and previously nonirrigated), overall mite populations were lowered to approximately equal levels. Complete flooding by border irrigation is better than flooding by corrugated furrows to lower mite populations. When irrigation is done by flooding listed furrows, the water often does not cover the tops of the ridges, and the undisturbed mites may migrate and become as numerous in a week on the plants in the furrows as on the ridges.

Brown wheat mite populations usually are much lower on summer-fallowed wheat than on continuously cropped wheat (Figure 7). If the land is fallowed following a wheat crop and summer eggs hatch from stubble or residue in the fall, the young mites will die from lack of food.

Controlling this pest with chemicals is difficult. Tests have shown that .5 pound of parathion per acre gave fair control of the mite, but did not increase the yield of wheat. It is believed that chemical control of the brown mite is not practical (16).

A WHITE MITE

A white mite, *Oligonychus pratensis* (Banks), is a pest of small grains in some parts of Texas. It differs from the other mites discussed here since it spins fine webbing on the plants. The mites are whitish or yellowish, and about half the size of the brown wheat mite. Feeding symptoms are similar to those of the brown wheat mite. During the fall when the wheat is small, the mites locate in small colonies on the leaves. During the winter, after the plants have tillered and temperatures are lower, they occur mainly in the crown of the plants near the soil surface. Infested plants can be detected by the presence of webbing in the crowns and usually an abnormal number of dead leaves. The mites generally remain at the plant bases until May, and then move to the upper leaves. Sometimes, wheat heads will become infested as they emerge from the boot. Controlling this pest with chemicals is not practical.

WHEAT CURL MITE

The wheat curl mite, *Aceria tulipae* (Keif.), which in a few instances has been found on the High Plains of

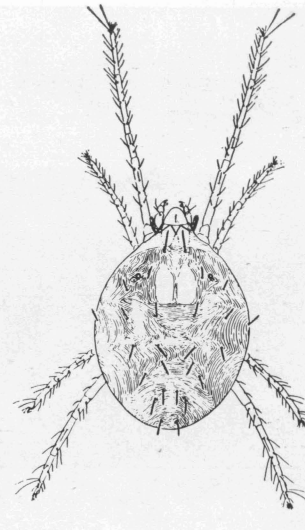

Figure 9. Drawing of an adult brown wheat mite, greatly enlarged. Courtesy of the Division of Agricultural Sciences, University of California.

Texas, is responsible for transmitting the virus wheat streak-mosaic. Transmitting mosaic is the only reason for the importance of this mite. Other damage done by it is slight and consists of curling and folding of the leaves causing "trapped leaves." Aphids also cause this condition, but do not transmit the virus. The wheat curl mite is white, spindle-shaped, with only four legs on the front of the body. These mites are so small that they are barely visible when magnified 10 times. They usually are found on the upper leaf surface of the plant and in the whorl. Eggs are laid in the grooves of the wheat leaf. The mites pass the summer between wheat crops on volunteer wheat and various grasses. They may be present on wheat without transmitting the mosaic. So far, no practical chemical control for this mite has been developed.

WINTER GRAIN MITE

The winter grain mite, *Penthaleus major* (Duges), causes considerable damage to fall-sown small grains, particularly in North Central and Central Texas. Banks (4) established the first record of this mite in the United States from Washington, D. C. It was reported damaging barley in Arizona in 1911 (unpublished manuscript by T. Scott Wilson). A county agent reported seeing this mite and its damage to small grains in Dallas county as early as 1919. Essig (12) and Campbell (5) discussed its damage to peas in California. Because of its economic damage to small grains, research on its biology and control was undertaken at the Denton station in 1952.

Small grains and grasses are the favored hosts of this mite, but it also feeds on legumes, weeds and vegetables. Heavily infested fields have a grayish or silvery appearance which is caused by the removal of chlorophyll and plant juices by the feeding mites (Figure 10). The plants die under heavy infestation. Loss in small grains is the reduced amount of forage during the winter and the reduced yields of grain in spring and summer.

The first-generation mites hatch in the fall, usually around November 1, from eggs which oversummered on grain stubble, straw or debris in the field. The dark brown to black mites (Figure 11) are about 1/25 inch in length and have four pairs of legs. The legs and mouthparts are reddish-orange. There usually is a reddish-

Figure 10. Winter grain mite damage. Field on left was in oats for 6 years continuously. Field on right was in clover the previous year. Denton, 1954.

orange spot on the back which surrounds the anus. The second generation develops in early January from eggs deposited by first-generation mites. Second-generation mites deposit the eggs that oversummer. When hot weather sets in, usually around April 15, all mites disappear from the fields.

Cool and moist conditions are necessary for mite development. Mites feed on the leaves mainly at night or on cloudy days; on bright days they hide under foliage on the moist soil surface. If the soil is dry, they burrow into it until they reach moisture. Light, loose soils are preferred.

Both cultural and chemical control recommendations for the winter grain mite have been developed as a result of research conducted at the Denton station. Fields planted to small grains continuously for 3 or more years usually were heavily infested and damaged. In fields where the previous crop was other than a small grain, such as cotton, corn, clover or sorghum, mites were either absent or very scarce, and there was no damage. Therefore, a

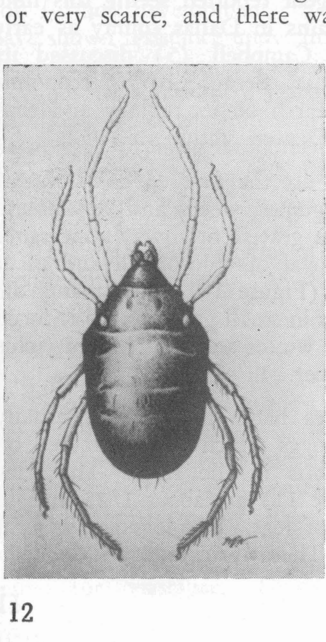

Figure 11. Winter grain mite adult, greatly enlarged.

change from continuous cropping of small grains to a rotation involving other crops at least every 2 years reduced greatly the damage caused by the winter grain mite. Several of the phosphorus compounds gave satisfactory control of the mite at relatively low dosages (6). Parathion at .25 pound or malathion at .5 to .75 pound per acre applied in a spray gave adequate control of the winter grain mite in small grains.

FALSE WIREWORMS

Several species of false wireworms, *Eleodes* spp., frequently cause damage to germinating wheat and sorghum in the small grain growing areas. Sorghum shares this important insect problem. False wireworms are native prairie insects that originally fed on roots and germinating seed of wild plants, chiefly grasses. They attack several crops, including newly sown wheat and sorghum seed.

The adult false wireworm or beetle hibernates in waste areas, along fence rows and in crevices. The white oblong eggs, covered with a sticky substance, are deposited in the spring and early summer. They are laid singly in dry soil .5 to 3 inches deep. In 10 to 14 days, the eggs hatch into yellow, hard-shelled cylindrical worms that turn darker as they become older. Some of them become as long as 1.5 inches as they pass through several instars, covering a period of about a year. They are not full grown until the year following egg deposition. Pupation then takes place and lasts about 20 days. Newly emerged adults appear during the summer and feed on seed and roots scattered through the soil until cold weather forces them into hibernation.

The larvae cause the greatest injury during dry fall seasons. They usually increase during dry years. Often wheat is seeded or "dusted in" in the fall and lies several weeks before rainfall starts germination, During this dry period, the larvae eat the germ of the kernels. The moisture content often varies within a field, resulting in spotted infestations. False wireworms injure young seedlings by cutting them off just below the soil surface, but this damage is not so common as damage to the seed. The worms also damage sorghum seed sown in the spring or early summer, especially if there is little moisture. They usually feed in the top 6 inches of the soil and come to the surface only when it becomes wet.

Clean culture and accumulated soil moisture associated with summer fallowing reduce the amount of injury; a cropping system of continuous wheat favors their development. Fallowed fields are less attractive to egg-laying adults and will tend to starve the larvae.

TABLE 5. EFFECT ON PLANT STAND OF SORGHUM SEED TREATMENTS WITH INSECTICIDE WETTABLE POWDERS TO CONTROL THE FALSE WIREWORM, BUSHLAND STATION, 1954

Insecticide	Ounces of actual toxicant per 100 pounds of seed	Number of plants per 60 feet of row
Aldrin 50%	2	108
Lindane 25%	2	107
Heptachlor 25%	2	105
Dieldrin 75%	1	94
BHC	3	79
Check	—	54

Control on sorghum was possible with some of the insecticides. Seed treatment tests have been conducted at the Amarillo station and PanTech Farms during the past few years. Lindane, aldrin and heptachlor at 2 ounces of actual toxicant per 100 pounds of sorghum seed gave satisfactory control in the summer of 1954, as shown in Table 5. Dieldrin at 1 ounce did not give as good control as the other chemicals, but in other tests, a 2-ounce dosage did give excellent control. BHC was the least effective. Germination was not affected by aldrin, lindane, haptachlor or dieldrin in these tests. However, germination was reduced in the BHC-treated plots.

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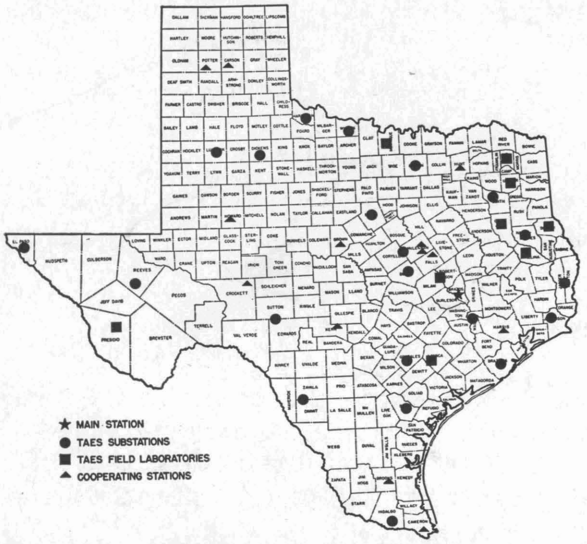

Location of field research units in Texas maintained by the Texas Agricultural Experiment Station and cooperating agencies

State-wide Research

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