# INHERITANCE OF RESISTANCE TO THE GREENBUG (TOXOPTERA GRAMINUM ROND.) IN WINTER BARLEY HYBRIDS

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By

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# INTRODUCTION

The greenbug (Toxoptera Graminum Rond.) is one of the most destructive insect pests of small grains in the central and southeastern states. According to Wadley (29)[1] it was first found by Rondoni in Italy in 1847 and was classified as Aphis graminum. In 1852 this species of insect was described by Rondoni more completely and placed in the genus Toxoptera. There is no definite proof of where this insect originated but the literature indicates that it came to this country from Europe.

This insect has caused some damage each year in the small-grain region of the United States and several severe outbreaks have been reported since the first specimens were found in 1882 near the Atlantic Coast (8).

In 1890 the first general outbreak occurred and caused damage to small grains in Texas, Oklahoma, Indiana, Illinois, Kentucky, and North Carolina. It was not until 1907 that a major outbreak occurred. It started in central Texas and spread in a fan-shaped area extending northward through Oklahoma, Kansas, Missouri, Arkansas and up into Illinois to within 60 miles of Chicago (2). This outbreak resulted in the abandoning of 70% of the wheat acreage in Texas and an estimated total loss of 50 million bushels of grain (30).

In addition to the severe outbreak of 1907 there have been 13 others. According to Dahms (8) the most serious one occurred in 1942 when in Texas and Oklahoma more than 61 million bushels of grain valued at 38 million dollars were lost. Also Dahms points out that in 1950 more than 1,500,000 acres of barley, oats, and wheat were abandoned because of the

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[1] Figures in parenthesis refer to "Literature Cited", page 54.

heavy infestation in northern Texas, western Oklahoma, and in some parts of Colorado, Kansas, and Nebraska.

The greenbug injures the small grain plant by puncturing the tissue and forcing the stylet down into the phloem region from which it takes up the life substance of the plant. However, as pointed out by Chatters and Schlehuber (7), the plant is probably damaged more by the introduction of the insect's saliva than by the uptake of the plant juices or by the mechanical injury. As the plants wither and die the greenbug moves out to new plants, leaving an area of dead plants. This area becomes larger and other similar areas in the field develop and soon all of these areas join causing a tremendous part of a field to be completely killed out.

There is a great deal of work being done on the control of greenbugs from various aspects such as cultural and natural controls and by the use of insecticides. Although these methods are very important and should be carried out, they are not enough during years of severe greenbug outbreaks. According to Dahms (8) insecticides were applied to more than 600,000 acres in northern Texas, western Oklahoma, and in some parts of Colorado, Kansas, and Nebraska in 1950. This does not appear to be a wholly satisfactory method of control because of the relatively low profit per acre from small grains and the high cost of applying the various chemicals. The most satisfactory answer to this problem lies in the incorporation of greenbug resistance into well adapted and desirable strains of small grains.

The purpose of this research was to determine the mode of inheritance of resistance of barley hybrids to artificially induced greenbug infestations. These studies were conducted under greenhouse conditions during the fall of 1950 and the spring and fall of 1951 at Stillwater, Oklahoma.

These greenhouse studies were designed to note the amount of growth made by each hybrid, to observe which hybrids were preferred by greenbugs, and to determine the actual number of days the hybrids would live under a heavy infestation of greenbugs as compared to the resistant and susceptible parents.

## REVIEW OF LITERATURE

Among the methods of preventing losses caused by insect pests, the breeding of insect resistant varieties has been and is now of major importance.

According to Jones (17), the earliest recorded observation of insect resistance was observed by Isaac Underhill in 1782 in wheat resistant to the hessian fly, (*Phytophaga destructor* Say). Today plant breeders, entomologists, plant physiologists, chemists, and possibly other specialists are cooperating in an effort to control injurious insects through the development of resistant varieties. As Dahms and Fenton (9) have pointed out, the principles involved in breeding for insect resistance are similar even though there are hundreds of insects and numerous crops.

The purpose of this brief resume is to review only the mode of inheritance of resistance of some of the grains and forages to a few of the more important insects.

### The Hessian Fly

Inheritance studies of wheat and other grains resistant to the hessian fly (*Phytophaga destructor* Say) have been carried on for more than 50 years and are today of major importance.

In the years 1904, 1905, and 1906, Gossard and Houser (15) made observations on 75 varieties of wheat and other grains, and found little support to the early idea that there are varieties immune to the hessian fly.

Later in experiments conducted by McColloch and Salmon (19) it was reported that the hessian fly could discriminate between different kinds and varieties of grain.

Painter (22) states that a high resistance among the durum spring wheats (Triticum durum) has been reported. Data presented gave evidence that a part of this resistance is the result of low oviposition on at least some of these wheats.

In studies by Painter and Jones (23) on the comparative amount of hessian fly resistance in Pawnee and Tenmarq wheat they found that Pawnee had 50% lower infestation in the main stem, 75% lower tiller infestation, decreased size of puparia, lower percentage of injury to infested plants, and higher yield under a heavy infestation of flies.

Painter, Salmon, and Parker (25) found that hessian fly resistance is an inherited character which may be combined with other desirable ones, but that this resistance is not closely linked with any agronomic character.

Crosses between resistant and susceptible wheat varieties have been studied by Parker and Painter (26), and they show that fly resistance is a heritable character, probably governed by multiple factors.

Experiments conducted by Painter, Jones, Johnston, and Parker (24) show that fly resistance can be transferred from Marquillo wheat to winter wheats. They found that there was no very close genetic relationship of hessian fly resistance with regard to disease resistance, winterhardiness, spring or winter habit of growth, or other visible agronomic characters.

Under California conditions the variety Dawson was shown to be highly resistant to fly attack, and the varieties Poso and Big Club were very susceptible as reported by Cartwright and Wiebe (6). From crosses of these three varieties they found that the inheritance of resistance to hessian fly gave a ratio closely approximating the theoretical 15:1 ratio occurring when two factors are involved. They therefore concluded that fly resistance in Dawson is heritable and is controlled by two genetic factors designated as $H_1H_1$ and $H_2H_2$. Later through backcrossing, they were able to transfer this resistance to commercial varieties. They also point out that resistant varieties interrupt the life cycle of the fly.

Further investigations carried on by Noble and Suneson (21) confirmed the results obtained by Cartwright and Wiebe. Their data also demonstrated the successful isolation, differentiation, and recombination of these two factors.

Varieties of common wheat found in previous work to be resistant to the hessian fly were used in crosses with W38 by Cartwright and Shands (5). They obtained results which indicated that at least two genes are involved with resistance being dominant; one gene coming from W38, designated as $H_3H_3$, and one or more being contributed by the other parent in the cross.

In addition to these three dominant resistant genes, Suneson and Noble (28) established that the variety Java contains an independent recessive gene pair designated $h_4h_4$.

Experimenting with two strains of the Java type wheat, Noble, Cartwright, and Suneson (20) found that these strains exhibited resistance to the fly similar to that exhibited by the variety Dawson. They concluded that it differed from Dawson by at least one factor.

## The Pea Aphid

Another insect of major importance is the pea aphid, (*Macrosiphum pisi* Kalt.). Blanchard (3) states that this pest has been partially controlled by certain cultural methods, but that the development of resistant strains seems to offer more possibilities.

In 1934 Blanchard and Dudley (4) observed in the field and in greenhouse tests, alfalfa plants which were practically immune to the pea aphid. They concluded that aphid resistance is an heritable character and to them it seemed evident that this resistance could be easily combined with agronomically desirable lines.

Albrecht and Chamberlain (1) in 1936 conducted experiments with $F_2$ hybrids of Dudley's resistant strains and obtained results similar to those obtained by Dudley. In a repetition of the tests in 1937, the results indicated that resistance was not a stable character and that inheritance of resistance is influenced to a great extent by its relation to environment.

A study of the rate of reproduction of the pea aphid on different alfalfa plants was conducted by Dahms and Painter in 1940 (12). They found that there existed a relationship between temperature and reproduction, and between resistance or susceptibility and mortality. They concluded that plants probably were resistant because they were able to withstand the feeding.

Experiments by Emery (14) showed that resistance of alfalfa to the pea aphid is correlated primarily with an acid condition and a scarcity or absence of sucrose in the plant. Also Emery found that resistance is due in part to the proportion of schlerenchymatous tissue and the amount of lignin in the walls of the parenchyma of the rays in the growing shoots.

Jones, Briggs, and Blanchard (18) crossed a resistant alfalfa plant, which they had selected from the progeny of a heterozygous resistant plant, with a susceptible one. They found that the $F_1$ plants were almost as resistant as the resistant parent. From the $F_2$ of the cross resistant X susceptible and the reciprocal, they obtained a 13:3 ratio which indicated the presence of one dominant and one recessive factor for resistance. They analyzed their data in another manner and the results indicated there was a single dominant factor for resistance to the pea aphid. Neither hypothesis was borne out by the $F_3$ data, but the $F_2$ data clearly indicated the presence of at least one recessive gene and probably one dominant gene for resistance. They point out that further study is needed to definitely explain the mode of inheritance.

## The Chinch Bug

The chinch bug (Blissus leucopterus Say) is of considerable importance in the Southwest, and a great deal of work has been done in an attempt to control it.

According to Dahms and Martin (11) resistance to chinch bugs in sorghums was dominant to susceptibility. Their work indicated that there was no association between hybrid vigor and chinch bug resistance as measured by oviposition and longevity of the females.

There was an increase in the resistance of sorghums to chinch bug attack by the addition of superphosphate to the soil as reported by

Dahms and Fenton (10). However, when sodium nitrate was added there was a decrease in resistance. They pointed out that the results from the pot experiments were variable.

Dahms, Snelling and Fenton (13) showed that the chinch bug passes through immature stages in less time on a susceptible variety of sorghums than on a resistant variety.

Results obtained by Snelling et.al. (27) suggest that resistance of sorghums to chinch bug attack is dominant or partially dominant. They concluded, however, that inheritance of chinch bug resistance is not governed by one main factor, but that it is more complex and is influenced not only by other genes directly affecting chinch bug reaction, but by genetic factors controlling agronomic characters. Lines which appeared to be homozygous for agronomic characters were found to be heterozygous for the genetic factors governing resistance or susceptibility. These authors also point out that natural selection is an important factor in chinch bug resistance in sorghums.

## The Greenbug

There has been relatively little work done in determining the mode of inheritance of resistance to the greenbug (*Toxoptera graminum* Rond.) in host plants. However, some valuable preliminary data have been reported by various workers in this field.

Some important controls of the greenbug as reported by Atkins and Dahms (2) include natural agencies, parasites, predators and unfavorable weather conditions. According to these workers, low temperatures during February and March, cloudy skies, little precipitation, low fertility of the soil, no previous crop such as cowpeas turned under, land preparation such as late fall plowed, and a low rate of seeding are important factors which favor greenbug outbreaks.

As pointed out by Dahms (8) all serious outbreaks have occurred when previous summers were cool and moist, followed by the conditions listed above. He further states that the greenbug population is usually kept in check by a small parasitic wasp, Aphidius testaclipes Cress. However, when the temperatures remain below 65° F. for long periods of time, the greenbug is able to increase to enormous numbers without much interference from the wasp. This is because the wasp reproduces much more slowly at these low temperatures. Also, it was found that both adult and larvae of lady beetles feed on the greenbug in some years and may aid materially in controlling them.

Dahms (8), also points out that when natural or cultural control is inadequate, insecticides such as parathion, Metacide, and tetraethyl pyrophosphate, can be used to suppress greenbug outbreaks.

Atkins and Dahms (2) have shown that a considerable number of barley varieties, mostly from Korea and east-central China are highly resistant to greenbug attack. They stated that this resistance is inherited and may be transmitted in crosses as evidenced by the high resistance which they found in Esaw (C.I. 4690)[2], Sunrise (C.I. 6272), and Smooth Awn 86 (C.I. 6268), all of which have the common parent Nakano Wase (C.I. 754), a resistant Japanese variety.

Experiments on the reaction of certain barley varieties to greenbug attack, by Grant (16) show that varieties which were most resistant

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[2] C.I. refers to accession number of the Division of Cereal Crops and Diseases.

were also least preferred, and the longevity of resistant varieties was closely correlated with their ability to tolerate severe infestations of aphids. He also found no correlation between agronomic characters of varieties and their ability to withstand attack by greenbugs.

From recent detailed cytological studies, Chatters and Schlehuber (7) reported that there appeared to be no direct correlation between the amounts of mechanical tissue in the leaves and stems of the barley, oats, and wheat plants which they studied, and susceptibility or resistance to the greenbug. At least in the case of the barley varieties studied, there was no relationship between the number of stomata and resistance. However, they found that plants of the resistant barley varieties had thicker leaves than the susceptible ones.

## MATERIALS AND METHODS

Hybrid populations from four winter barley crosses were subjected to artificial infestation with greenbugs in the Entomology greenhouse at Stillwater, Oklahoma, during 1950 and 1951. The parent varieties involved in these crosses were Omugi (C.I. 5144) and Dobaku (C.I. 5238) of Korean origin, an unnamed variety (C.I. 5087) of Chinese origin, Tenkow (C.I. 646) and Ward (C.I. 6007). The first three varieties were selected because of their indicated resistance to greenbugs as reported by previous workers. The two latter varieties, which are highly susceptible, were selected because they are the leading barley varieties in Oklahoma. All of the varieties are six-rowed types with covered seed. Omugi, Tenkow, and Ward have rough awns and lax heads. Dobaku also has rough awns but has compact heads. C.I. 5087 is an intermediate hooded type with lax heads.

Since there were only limited numbers of crossed seed for the $F_1$ study most of the emphasis was placed on the study of the $F_2$ generation.

### $F_2$ Hybrid Tests

The four crosses studied were tested separately and were assigned "set" numbers as shown in Table 1.

Seed of the parents of sets I and II was from actual parent lines, that is, increases from the exact parent plants used in these crosses. For sets III and IV, however, seed of the actual parent lines was not available so that parent checks were planted from bulk lots of seed of the proper varieties. All of the $F_2$, parent, and check seed was

Table 1.--The total number of check, parent, and hybrid plants included in the $F_2$ study according to set number and date planted.

| Set | Date Planted | Variety or Cross | Number of plants |
|---|---|---|---|
| I | October 4, 1950 | Omugi (ck.) | 40 |
| | | Dobaku (8-25) | 40 |
| | | Ward (1-37) | 40 |
| | | Dobaku x Ward $F_2$ | 199 |
| II | November 21, 1950 | Omugi (ck.) | 39 |
| | | Dobaku (8-12) | 39 |
| | | C.I. 5087 (9-4) | 40 |
| | | Dobaku x C.I. 5087 $F_2$ | 200 |
| III | January 13, 1951 | Omugi | 40 |
| | | Tenkow | 39 |
| | | Omugi x Tenkow $F_2$ | 227 |
| IV | February 27, 1951 | Omugi | 39 |
| | | Ward | 38 |
| | | Omugi x Ward $F_2$ | 233 |

obtained from the Agronomy Department, Oklahoma Agricultural and Mechanical College.

Original plans called for the use of 40 six-inch pots per set with each pot to contain eight seedlings at the time of infestation. The seed was planted at random in rows radiating out from the center of each pot. Three seeds were planted in a single row for each of the two parents and the check variety. This was done to insure a perfect stand of these varieties in each pot. Single $F_2$ seeds were planted in the remaining rows in each pot. Due to poor germination and damage a few seedlings were lost. In sets I and II Omugi was planted as a resistant check so that only five $F_2$ seeds were included in each pot. In sets III and IV Omugi was one of the parents so that six $F_2$ seeds were planted in each pot. Actual numbers of hybrid, parent, and check plants in each set are indicated in Table 1.

The seed was covered uniformly with finely screened sandy loam soil relatively high in organic matter content, and all from the same source. All preparations for planting, such as screening the soil and filling the pots were done in a uniform manner.

After seeding, the pots were placed in watering pans three inches deep and large enough to hold 20 pots. By this method of watering it was possible to keep the seed from shifting around in the pots. However, in several cases where the soil in the pots would not absorb the water it was necessary to water them carefully from the top with a sprinkling can. Most of the pots in all four sets did absorb the water readily.

Three days after emergence, the parents and the check were thinned to one plant per row. In thinning, uniformly vigorous seedlings of approximately the same size were selected, but in many cases the location of the seedling was a determining factor. It was essential to have the plants within a certain radius in the pots in order to assure equal chance for all plants to become infested with greenbugs at the time of infestation. The plants were allowed to grow for a period of approximately six days after thinning to give them a chance to overcome any disturbance which may have occurred at the time of thinning (See Fig. 1).

Two weeks after seeding, each plant was measured to the nearest one-half centimeter. This was done by placing a centimeter scale beside the plant and stretching the longest leaf to its full length and reading the measurement directly from the scale. Immediately after taking the measurements, the pots were infested with greenbug nymphs, three to six days old. The nymphs were taken at random from a stock culture which has been carried on various greenbug-susceptible barley varieties since 1947 by Dr. R. G. Dahms[3]. Each pot was infested at the rate of five bugs per plant or 40 bugs per pot. In several pots there were less than eight plants due to poor germination, as previously mentioned, and therefore the total number of greenbugs was less than 40. To obtain the greenbugs for the infestation individual plants were clipped from stock culture increase pots, and the nymphs were brushed from the clipped plants with a small camel's-hair brush onto a piece of flat white paper. When the correct number of nymphs was on the paper,

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[3] Entomologist, Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine, U.S.D.A. Stillwater, Oklahoma.

Fig. 1.--Parental and hybrid seedlings of Set IV immediately prior to artificial infestation with greenbugs in the greenhouse at Stillwater, Oklahoma, 1951.

the paper was folded to form a funnel-like structure and placed in the center of the pot which was to be infested. By tapping the paper gently all nymphs could be easily deposited in the center of the pot. In approximately three to five minutes the majority of the nymphs had found their way to a barley plant and were feeding.

As each of the pots was infested, a celluloid cage 10 inches high and 5 inches in diameter was placed over the plants (See Fig. 2). The top of each cage was closed with a fine mesh muslin and the bottom which was left open was placed in the soil around the plants as shown in Figure 3. This provided a cage which was practically greenbug proof, well aerated, and transparent, through which observations and rating of plants easily could be made.

During each of the first four days after infestation, a count was made of the number of greenbugs on each plant. This count usually was taken between 8 and 12 a.m. The pots were rearranged daily to help compensate for any differences due to location or position in the greenhouse.

Beginning on the fifth day after infestation all plants were examined daily for greenbug damage. This was done between 8 and 10 a.m. and each plant was rated according to the following scale:

| Rating of Plant | Estimated Percent of Damage to Plant |
|---|---|
| 0 | 0 - 10 |
| 1 | 11 - 35 |
| 2 | 36 - 60 |
| 3 | 61 - 80 |
| 4 | 81 - 99 |
| 5 | 100 |

In order to allow for injuries not due to greenbugs in the early


Fig. 2.--Individual pot with cage removed showing cheesecloth top and open bottom. Picture was taken six weeks after infestation at which time three plants still were alive.

Fig. 3.--Parental and hybrid seedlings of Set II immediately after artificial infestation with greenbugs in the greenhouse at Stillwater, Oklahoma, 1950.

part of the test the plants were rated zero (0) until more than 10% damage was apparent. The form on which daily ratings were recorded was like that used by previous workers (See Appendix Table 1).

As soon as all plants in a pot were completely dead the cage was removed and the plants were again measured to the nearest one-half centimeter.

Set I was started and kept outside of the greenhouse for approximately three weeks because of the excessively high temperatures that prevailed inside. The average shade-air temperature outside during this period was approximately 70° F. During the rest of the experiment in the greenhouse the temperatures were fairly constant averaging between 65° and 70° F.

Ratings were made for a period of 46 days on Set I, 92 days on Set II, 34 days on Set III, and 40 days on Set IV. However, approximately 85% of the plants in Set II lived only for a period of 20 to 30 days. One $F_2$ plant in Pot 30 was rated for 92 days at which time it was beginning to recover from the greenbug attack. This plant was allowed to reach maturity and the seed was collected for further testing.

The analysis of variance method was used to analyze the parental and check data from all four sets from the following aspects:

1. Preference of greenbugs for certain plants.
2. Tolerance of plants to greenbug attack.
   a. As measured by the accumulated ratings.
   b. As measured by the amount of growth.

The preference of greenbugs for a given plant was determined by adding together the number of aphids on that plant each day for the first four days. This period was selected because no plant was rated as damaged until after the fourth day. After this period the aphids probably would have moved to other plants seeking more succulence, since the plant they were on may have become injured.

The tolerance of a plant to greenbug attack as measured by its accumulated rating refers to a "total rating value" given to each plant. This value was calculated by multiplying the number of days the plant received a given rating by the assigned value for that rating. The total value from all of the ratings for a given plant was then determined. The scale of plant ratings and the corresponding assigned values used were as follows:

| Rating of Plant | Assigned Value |
|---|---|
| 0 | 10 |
| 1 | 7 |
| 2 | 5 |
| 3 | 3 |
| 4 | 1 |
| 5 | 0 |

In determining the tolerance of a given plant it was believed desirable to assign the above values in order to place more emphasis on the "resistant" ratings.

Tolerance of plants to greenbug attack as measured by the amount of growth made by each plant during the period of infestation was determined by subtracting the original "height" of a given plant from its "height" at the end of the test.

Data from the preference and tolerance tests are presented in the form of graphs for all sets in an attempt to explain more fully the mode of inheritance of resistance to the greenbug in barley hybrids.

## $F_1$ Hybrid Tests

$F_1$ hybrid plants from three of the four winter barley crosses previously mentioned and their reciprocals were subjected to artificial infestation with greenbugs. There were no crosses successfully made between Dobaku and C.I. 5087. Tables 2 and 3 show the number of seedlings tested and the date each was planted in addition to the distribution of parent and hybrid plants as based on the amount of growth and accumulated rating.

Crossed seed of Omugi X Tenkow planted March 3, 1951, was furnished by the Agronomy Department, Oklahoma Agricultural and Mechanical College and all other crossed seed was obtained by the author from crosses made during May, 1951, at the Agronomy Farm, Stillwater, Oklahoma.

The $F_1$ plants were tested in the same manner as was reported for the $F_2$ plants, but the $F_1$ data were not analyzed in the same way as that described for the $F_2$ data because of the small populations which were obtained. However, these data were used for comparison with the $F_2$ results.

Table 2.--Distribution of individual $F_1$ hybrid and parent plants according to amount of growth made during the period of infestation with greenbugs in the greenhouse at Stillwater, Oklahoma.

| Parent or Cross | Amount of Growth (centimeters)* | | | | | | | | Total Plants |
|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 4.5 | 7.5 | 10.5 | 13.5 | 16.5 | 19.5 | 22.5 | |
| | | | | Seeded March 3, 1951 | | | | | |
| Omugi | 1 | | 3 | | | | | | 4 |
| Tenkow | 3 | 1 | | | | | | | 4 |
| Omugi x Tenkow $F_1$ | 1 | 2 | 4 | | | | | | 7 |
| Tenkow x Omugi $F_1$ | | 7 | 1 | | | | | | 8 |
| | | | | Seeded October 27, 1951 | | | | | |
| Omugi | | | | 1 | 3 | | 1 | | 5 |
| Tenkow | | 1 | 2 | 1 | 1 | | | | 5 |
| Omugi x Tenkow $F_1$ | | | | 2 | 3 | 4 | 2 | 4 | 15 |
| Tenkow x Omugi $F_1$ | | | | 1 | | 2 | | | 3 |
| | | | | | | | | | |
| Omugi | | | | | | 2 | 1 | | 3 |
| Ward | | 1 | | 2 | | | | | 3 |
| Omugi x Ward $F_1$ | | | | | 1 | | 3 | 8 | 12 |
| Ward x Omugi $F_1$ | | | | 2 | | | 1 | | 3 |
| | | | | | | | | | |
| Dobaku | | | | | | 1 | 1 | | 2 |
| Ward | | | 1 | | 1 | | | | 2 |
| Dobaku x Ward $F_1$ | | | | 1 | | | | | 1 |
| Ward x Dobaku $F_1$ | | 1 | 1 | | 3 | | | | 5 |

*Growth made after infestation.

Table 3.--Distribution of individual $F_1$ hybrid and parent plants according to accumulated rating (tolerance) during the period of infestation with greenbugs in the greenhouse at Stillwater, Oklahoma.

| Parent or Cross | Accumulated Rating | | | | | | | | | | | | | | Total Plants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 55 | 65 | 75 | 85 | 95 | 105 | 115 | 125 | 135 | 145 | 155 | 165 | 175 | 185 | |
| Seeded March 3, 1951 | | | | | | | | | | | | | | | |
| Omugi | | | | | 1 | | | | 2 | 1 | | | | | 4 |
| Tenkow | | | 2 | | 1 | 1 | | | | | | | | | 4 |
| Omugi x Tenkow $F_1$ | | 1 | | | 1 | 2 | 2 | 1 | | | | | | | 7 |
| Tenkow x Omugi $F_1$ | 2 | 1 | 1 | 1 | 1 | 2 | | | | | | | | | 8 |
| Seeded October 27, 1951 | | | | | | | | | | | | | | | |
| Omugi | | | | | | 1 | 1 | | 1 | 1 | | 1 | | | 5 |
| Tenkow | | | 1 | | 1 | | 3 | | | | | | | | 5 |
| Omugi x Tenkow $F_1$ | | | 2 | | | | 2 | 2 | 2 | 4 | 2 | 1 | | | 15 |
| Tenkow x Omugi $F_1$ | | | | | | 1 | | 2 | | | | | | | 3 |
| Dobaku | | | | | | | | 1 | | | 1 | | | | 2 |
| Ward | | | 1 | | 1 | | | | | | | | | | 2 |
| Dobaku x Ward $F_1$ | | | | | | 1 | | | | | | | | | 1 |
| Ward x Dobaku $F_1$ | | | 2 | | 1 | | | 1 | | 1 | | | | | 5 |
| Omugi | | | | | | | | | | | 3 | | | | 3 |
| Ward | | | | | 2 | | | | | 1 | | | | | 3 |
| Omugi x Ward $F_1$ | | | | | | | | | | | 3 | 2 | 3 | 4 | 12 |
| Ward x Omugi $F_1$ | | | 1 | | | | 1 | | | | 1 | | | | 3 |

## EXPERIMENTAL RESULTS

### $F_1$ Tests

Although the number of $F_1$ plants tested was quite small the hybrid plants in general were considerably more resistant than the susceptible parent plants, especially as indicated by the amount of growth test (See Tables 2 and 3). From the distribution of the data presented in these two tables it can be seen that the difference in the reaction between the resistant and the susceptible parent plants was much less in the March 3 test than in the later test. Also the $F_1$ hybrids tended to produce an intermediate type of reaction in the March 3 test. The fact that the seed for the March 3 test was obtained from the Agronomy Department and was grown at a different location and under different environmental conditions than the seed for the October 27 tests would perhaps help explain the different type of reaction observed. The seed in the March 3 test was crossed and grown in the greenhouse at Ames, Iowa, with watering as needed, whereas the seed for the October 27 test was crossed and grown at Stillwater, Oklahoma, under dryland conditions.

The preference data from the $F_1$ test were not used because the parent distribution was highly erratic. It did not appear that a true indication was obtained for this criterion of measuring the resistance of hybrids to greenbug attack.

### Analysis of Parental and Check Data

Mean square values from the analysis of variance of the parental and check data from each of the four sets included in the $F_2$ study are presented in Table 4. As indicated previously the data were analyzed for the preference, accumulated rating, and the amount of growth tests.

The analysis from the preference test indicates that in each of the four crosses or sets there was no significant difference between replications (.05 point). Data from sets I, II, and III showed a highly significant difference (.01 point) between varieties, but the data from set IV showed no significant difference (.05 point) between varieties. Previous work at the Oklahoma station has indicated that Omugi and Dobaku are highly resistant to greenbugs and that C.I. 5087 is moderately resistant, and that Tenkow and Ward are highly susceptible (16). The behavior of Ward and Omugi (Set IV) appears to have been somewhat abnormal in this preference test.

Analysis of the accumulated rating data for all four crosses studied indicates a highly significant difference (.01 point) between both varieties and replications except in Set III which shows no significant difference (.05 point) between replications. As stated previously the varieties are known to be of a different type of reaction to greenbug attack. The results for this criterion of measurement are therefore in agreement with what normally would be expected. However, the expected results from between replications was obtained only in Set III. Sets I, II and IV evidently had environmental influences brought into them.

Analysis of the data for tolerance of barley to greenbug attack as measured by the amount of growth indicates that there is a highly

Table 4.--Analyses of variance of parental and check data of the preference and tolerance tests (Sets I, II, III, and IV) in greenhouse tests at Stillwater, Oklahoma, 1950-51.

| Source of Variation | D.F. | Mean Squares: Preference | Mean Squares: Accumulated Rating | Mean Squares: Amount of Growth |
|---|---|---|---|---|
| Set I - Dobaku, Ward and Omugi check | | | | |
| Total | 119 | | | |
| Reps. | 39 | 644 | 2,179** | 45* |
| Vars. | 2 | 4,727** | 19,128** | 1,182** |
| Errors | 78 | 429 | 542 | 26 |
| Set II - Dobaku, C.I. 5087, and Omugi check | | | | |
| Total | 116 | | | |
| Reps. | 38 | 186 | 2,658** | 35** |
| Vars. | 2 | 1,404** | 4,851** | 557** |
| Error | 76 | 164 | 221 | 12 |
| Set III - Omugi and Tenkow | | | | |
| Total | 77 | | | |
| Reps. | 38 | 208 | 382 | 35* |
| Vars. | 1 | 6,647** | 17,490** | 786** |
| Error | 38 | 207 | 248 | 17 |
| Set IV - Omugi and Ward | | | | |
| Total | 73 (71)*** | | | |
| Reps. | 36 (35) | 427 | 780** | 26* |
| Vars. | 1 ( 1) | 1,386 | 16,501** | 879** |
| Error | 36 (35) | 429 | 289 | 14 |

*Significant at the 5% level.

**Significant at the 1% level.

***Degrees of freedom for the preference test. Because Omugi in one pot had no greenbugs on it during the four day period this pot was omitted in the analysis.

significant difference (.01 point) between varieties in all crosses but only a slightly significant difference (.05 point) between replications or pots. Set II shows a highly significant difference (.01 point) between replications. The explanation given for the accumulated rating analysis also would apply to these results.

Inasmuch as there is a significant difference (.05 point) between replications for the accumulated rating test and the amount of growth test, the graphs for sets I and II for these data are presented in relation to the Omugi check. In sets III and IV Omugi was a parent of the cross and therefore graph presentations are given on a direct basis.

## $F_2$ Tests

Data for the tolerance and preference tests of the four crosses are presented graphically according to the distribution of the parent, check, and $F_2$ plants.

Classification of the $F_2$ plants for resistance and susceptibility in all four crosses as measured by the amount of growth and accumulated rating was determined by using the point at which the lines representing the distribution of the two parents cross each other. The determining of this point was in relation to the averages of the parent, check, and $F_2$ plants. In addition to this evidence for separating the $F_2$ plants there is, in general, a break in the distribution curve of the $F_2$ plants at this point or the line representing the $F_2$ distribution is approaching a natural breaking point.

Resistance as measured by the preference of greenbugs for certain barley plants does not show a satisfactory distribution of the parent plants (See Figs. 6, 9, 12, and 15). For this reason the $F_2$ plants were not classified for resistance and susceptibility to greenbug attack as based on this test. The data are used only for confirming the results of the other two tests as presented by the average trend in the preference test.

There is some overlapping of the parents for the accumulated rating and amount of growth tests of each cross, but it could be assumed that the same phenomenon is taking place in the classification of the $F_2$ plants. The fact that each test or measurement supports the other in all sets provides evidence that the assumptions probably are correct for classification of plants as to resistance or susceptibility to greenbug attack.

## Set I -- Dobaku X Ward

The graphic presentation for the accumulated rating test indicates that the mean for the $F_2$ plants is between that of the two parents; however, it is closer to the mean of the resistant parent (Fig. 4)[4]. The average of the $F_2$ plants is 100% of the Omugi check, the Dobaku average is 103%, and the Ward average is 83%. All plants with a rating of 92% and less were classified as susceptible and those with 93% and above as resistant.

Results from the amount of growth test, as shown in Figure 5, indicate that there is very little difference between the mean of the resistant parent and the mean of the $F_2$ plants. The average growth of the $F_2$ plants during infestation was 115% of Omugi as compared to an

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[4]See App. Tables 2, 3, and 4 for the actual data.

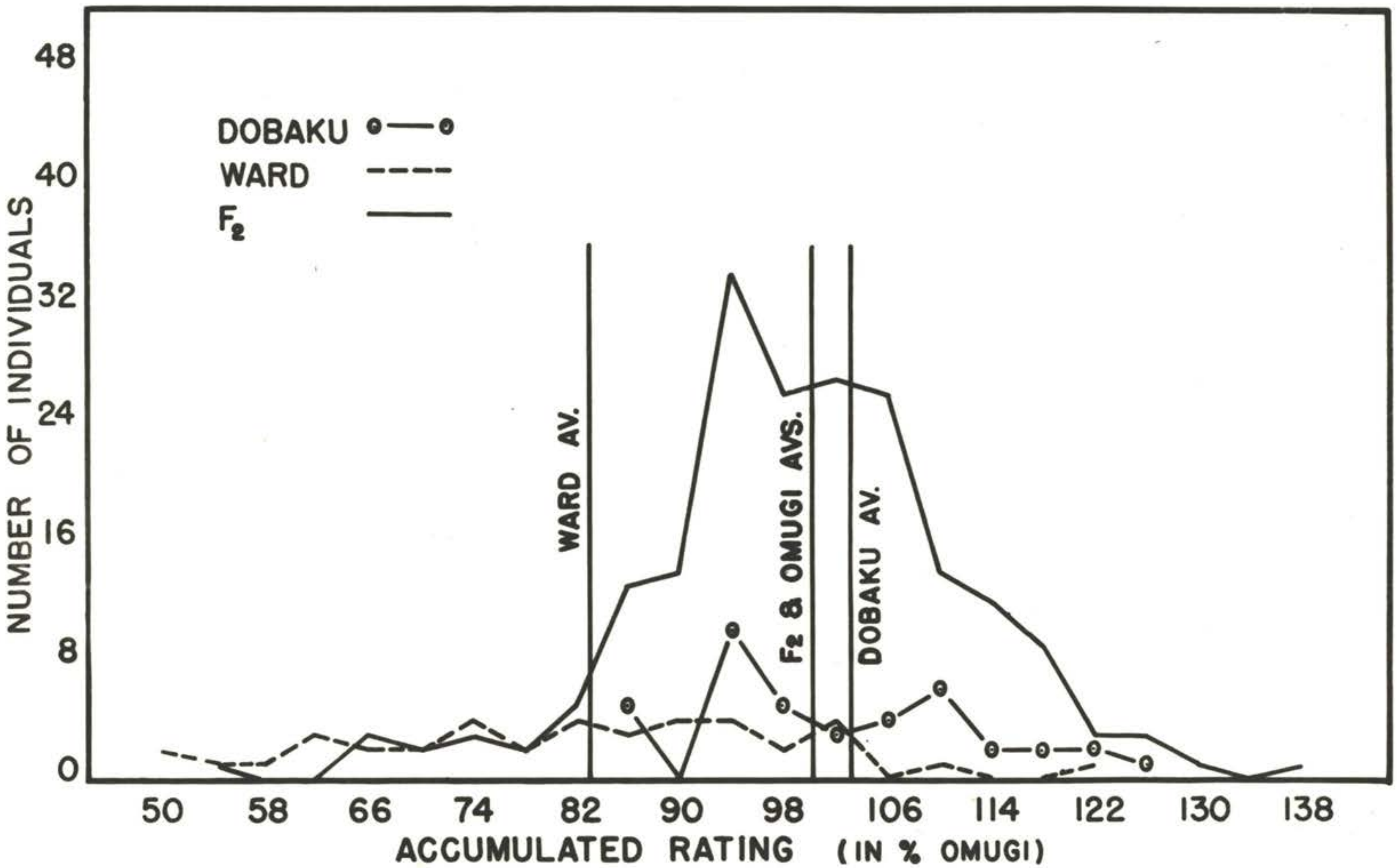


Fig. 4.--Distribution of parent and $F_2$ plants of Dobaku x Ward by accumulated rating classes when tested under artificial infestation of greenbugs at Stillwater, Oklahoma, 1950-51.

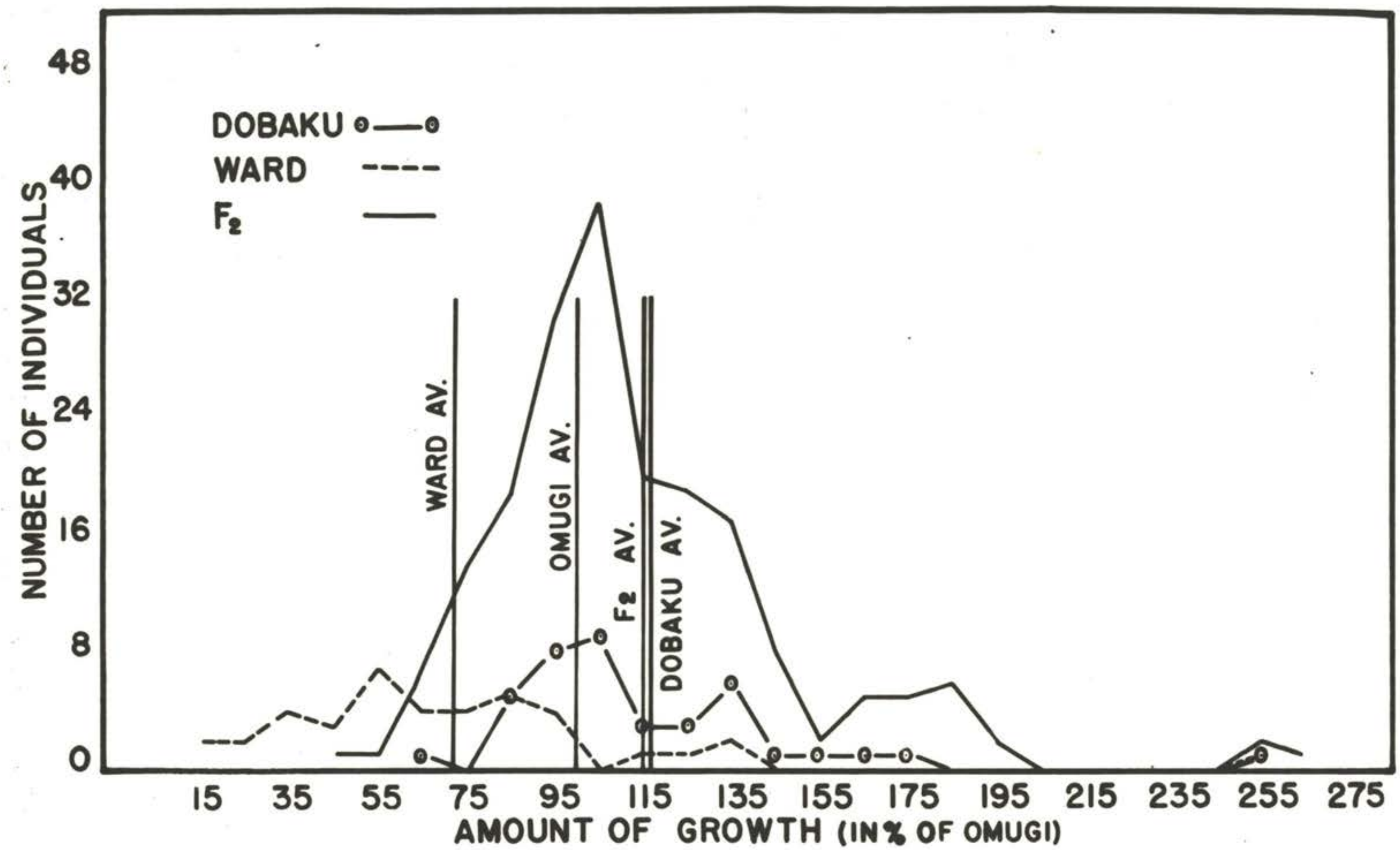


Fig. 5.--Distribution of parent and $F_2$ plants of Dobaku x Ward by amount of growth classes when tested under artificial infestation of greenbugs at Stillwater, Oklahoma, 1950-51.

average of 116% for Dobaku. During this same period Ward showed an average growth of only 72% of Omugi. The $F_2$ plants were classified as susceptible if the amount of growth was 85% of the Omugi check or less. A resistant plant was therefore one with a growth of more than 85%.

According to the data for the preference test (Fig. 6) the $F_2$ plants had an average infestation of 30.9 greenbugs per plant as compared to 41.9 for Ward. The $F_2$ plants, on the average, were more preferred than the resistant parent, Dobaku, and the Omugi check which had average infestations of 23.3 and 22.9 respectively.

If the results have been interpreted correctly the tolerance tests indicate an observed segregation of 156:43 for the accumulated rating test, and 162:37 for the amount of growth test. For a 13:3 ratio, totals of 160 resistant and 39 susceptible plants would be expected. The probability that the 13:3 ratio hypothesized for this cross is correct is 30% to 50% for the accumulated rating test and 50% to 70% for the amount of growth test (See Table 5). According to the average preference of greenbugs for the parent, check and $F_2$ plants and the $F_2$ distribution for this test (Fig. 6) indications are that resistance is dominant. Because this is in close agreement with the tolerance tests additional evidence is provided for the correctness of the assumption.

From these data it appears reasonable that there is one dominant and one recessive factor for greenbug resistance. If this is true the resistant parent, Dobaku, would have a genotype of $Grb_1$ $Grb_1$ $grb_2$ $grb_2$ /5

/5 Symbols refer to the genes for greenbug resistance and are assigned at this time by the author.

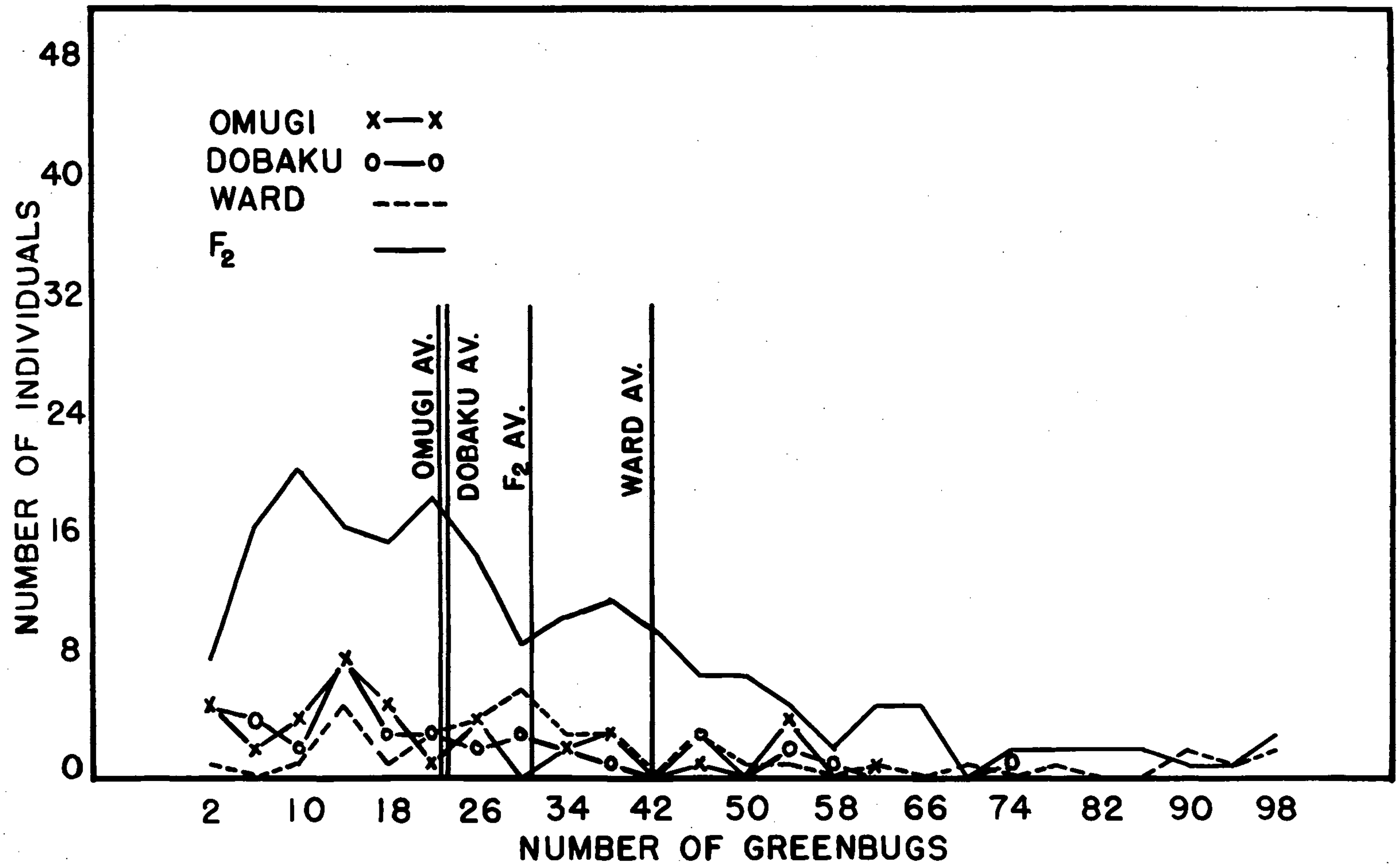


Fig. 6.--Distribution of parent, check, and $F_2$ plants of Dobaku x Ward by preference of greenbugs when tested under artificial infestation at Stillwater, Oklahoma, 1950-51.

Table 5.--Inheritance of resistance to artificial infestation of greenbugs in four winter barley crosses at Stillwater, Oklahoma, 1950-51.

| Test | Observed or Expected* | Resistant | Susceptible | Chi-square | P value |
|---|---|---|---|---|---|
| | | Set I - Dobaku x Ward | | | |
| Accumulated Rating | Obs. | 156 | 43 | 0.510 | .30 - .50 |
| | E(13:3) | 160 | 39 | | |
| Amount of Growth | Obs. | 162 | 37 | 0.128 | .50 - .70 |
| | E(13:3) | 160 | 39 | | |
| | | Set II - Dobaku x C.I. 5087 | | | |
| Accumulated Rating | Obs. | 146 | 54 | 0.427 | .50 - .70 |
| | E(3:1) | 150 | 50 | | |
| Amount of Growth | Obs. | 145 | 55 | 0.667 | .30 - .50 |
| | E(3:1) | 150 | 50 | | |
| | | Set III - Omugi x Tenkow | | | |
| Accumulated Rating | Obs. | 136 | 91 | 1.146 | .20 - .30 |
| | E(9:7) | 128 | 99 | | |
| Amount of Growth | Obs. | 122 | 105 | 0.645 | .30 - .50 |
| | E(9:7) | 128 | 99 | | |
| | | Set IV - Omugi x Ward | | | |
| Accumulated Rating | Obs. | 181 | 52 | 0.827 | .30 - .50 |
| | E(3:1) | 175 | 58 | | |
| Amount of Growth | Obs. | 173 | 60 | 0.092 | .70 - .80 |
| | E(3:1) | 175 | 58 | | |

*Obs. means observed number and E means the expected number.

and Ward parent would be of the genotype $grb_1\ grb_1\ Grb_2\ Grb_2$.

Set II --Dobaku X C.I. 5087

Data for resistance as measured by the accumulated rating shows an average of 100% of Omugi for the $F_2$ plants and an average of 104% for Dobaku as compared to only 92% for C.I. 5087 (Fig. 7). As was the situation in Set I, the average for the $F_2$ plants of this cross is closer to that of the resistant parent.

The $F_2$ plants were classified as resistant to greenbug attack if they had an accumulated rating above 96% of Omugi and those with 96% and below were classed as susceptible.

The average increase in height for the $F_2$ plants during the period of infestation was 106.8% of Omugi (Fig. 8). This is considerably more than the 78.2% for the susceptible parent, but less than the 126% for the resistant parent. Classification of the $F_2$ population for resistance and susceptibility was based on the following: plants which had an amount of growth of 85% of the Omugi check and less were classed as susceptible, and those with an amount of growth more than this were classed as resistant.

As shown by the preference graph, (Fig. 9) the $F_2$ plants on an average were less preferred by the greenbugs than were the C.I. 5087 parent plants. The $F_2$ plants had an average infestation of 18.6 greenbugs per plant as compared to 14.9 for Dobaku, 16.6 for the Omugi check, and 24 for the susceptible parent, C.I. 5087. As previously stated classification for resistance and susceptibility was not determined for the preference test because of the erratic distribution of the parent plants.

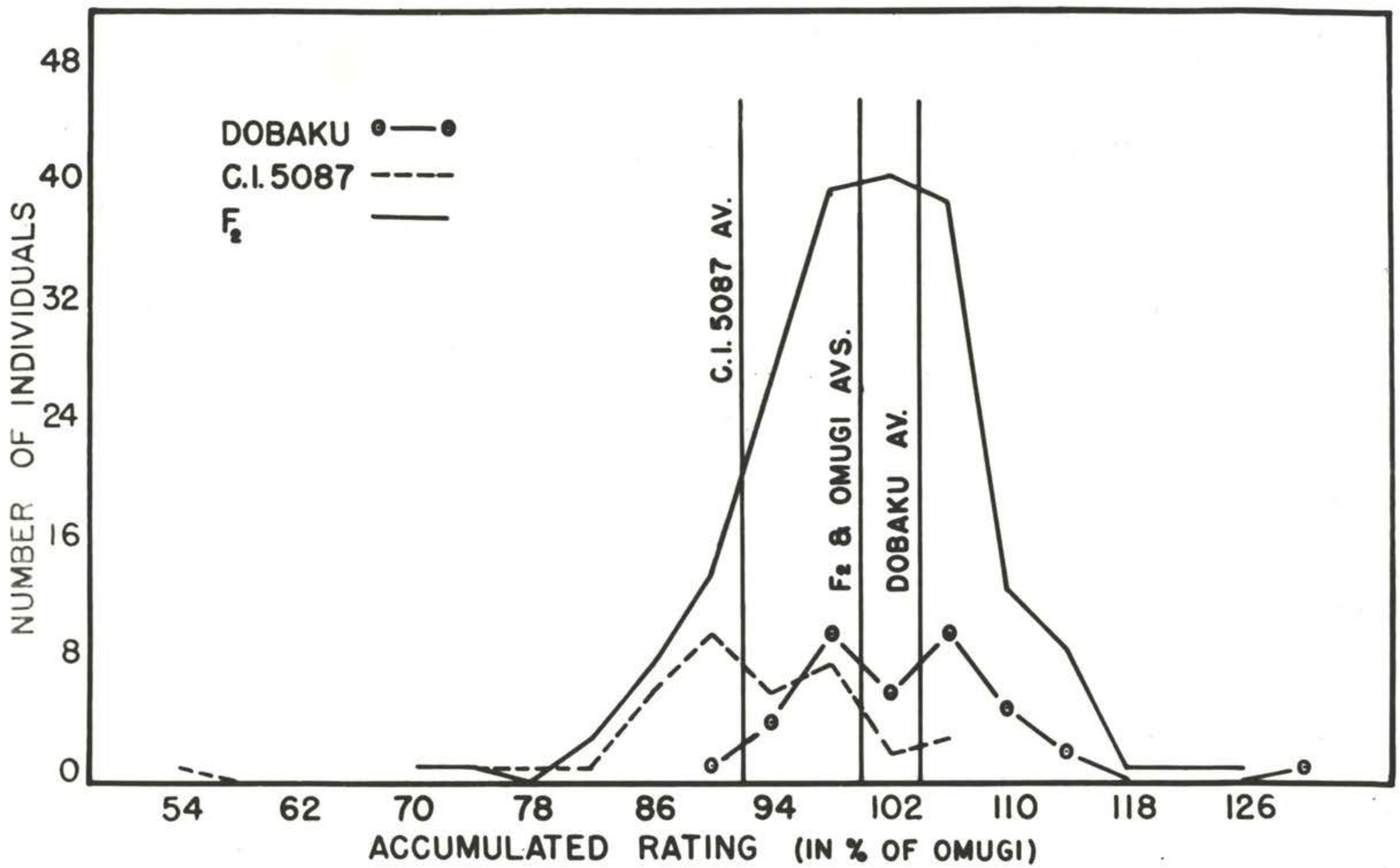


Fig. 7.--Distribution of parent and $F_2$ plants of Dobaku x C.I. 5087 by accumulated rating classes when tested under artificial infestation of greenbugs at Stillwater, Oklahoma, 1950-51.

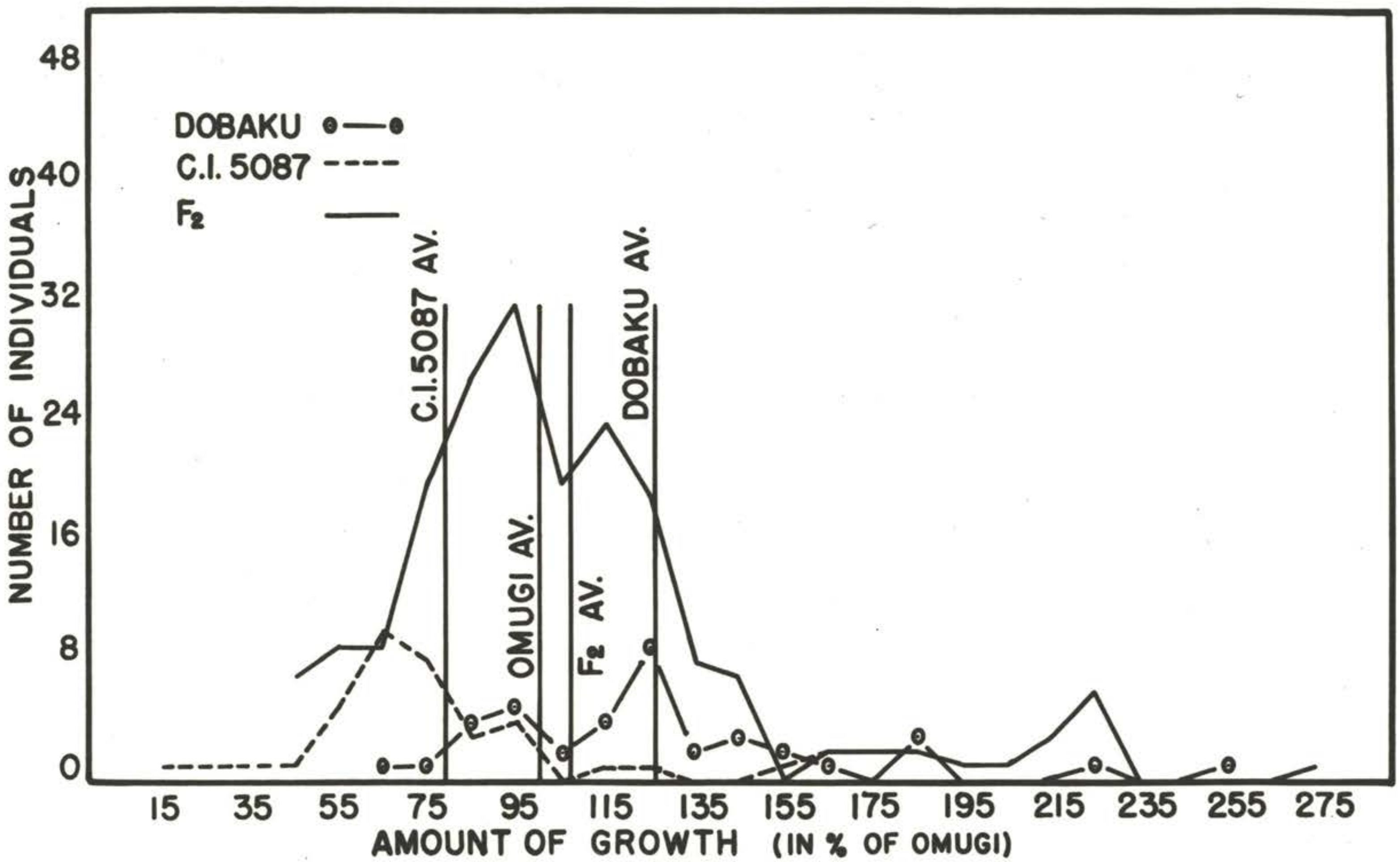


Fig. 8.--Distribution of parent and $F_2$ plants of Dobaku x C.I. 5087 by amount of growth classes when tested under artificial infestation of greenbugs at Stillwater, Oklahoma, 1950-51.

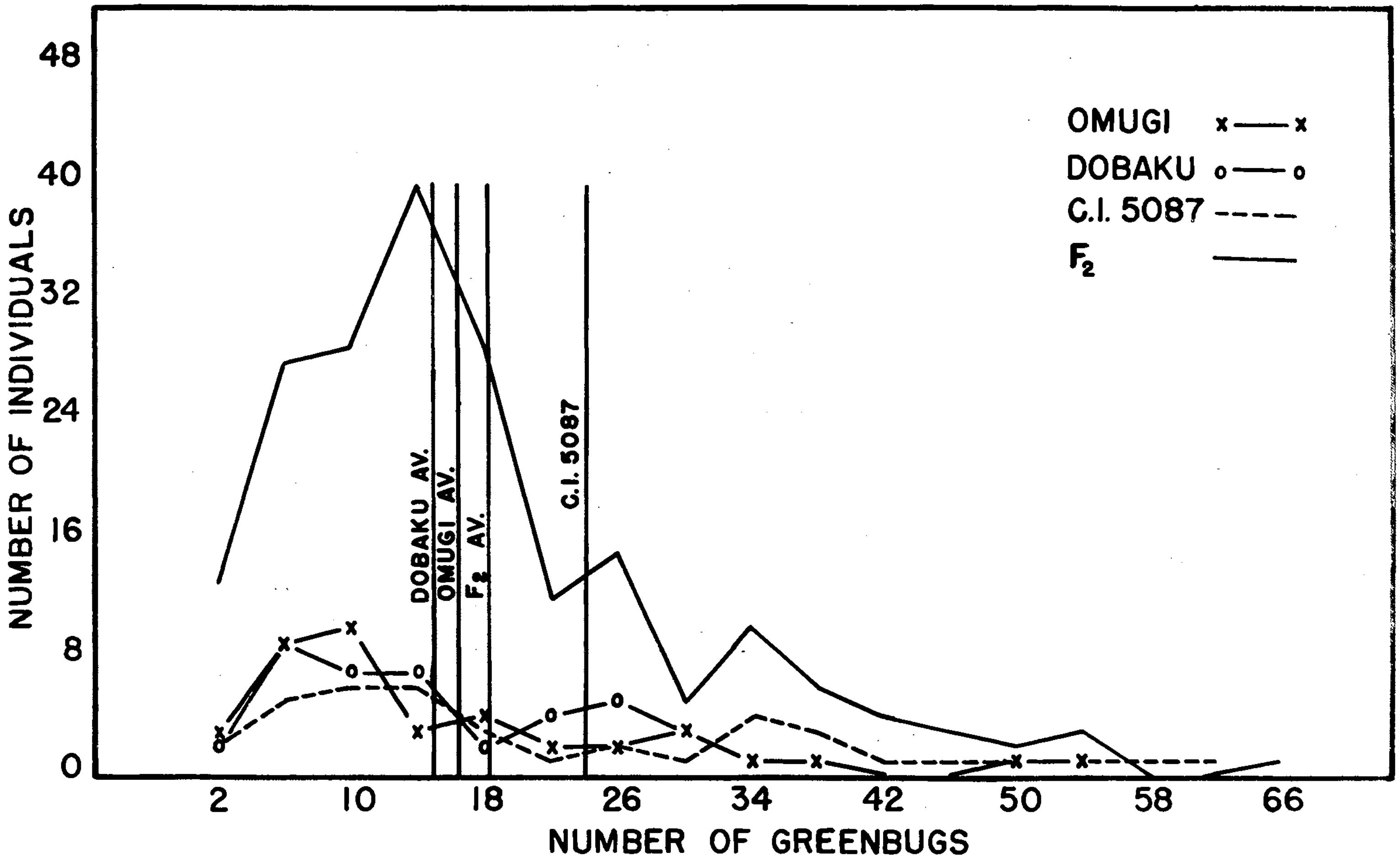


Fig. 9.--Distribution of parent, check, and $F_2$ plants of Dobaku x C.I. 5087 by preference of greenbugs when tested under artificial infestation at Stillwater, Oklahoma, 1950-51.

The data for the accumulated rating test and the amount of growth test indicate an observed number of resistant and susceptible $F_2$ plants of 146:54 and 145:55 respectively. The theoretical number expected for a 3:1 ratio is 150 resistant and 50 susceptible. Provided the assumptions are correct, the probability that these observed numbers fit the ratio hypothesized is 50% to 70% for the accumulated rating test and 30% to 50% for the amount of growth test (See Table 5).

The preference test provides additional support in that the distribution of the $F_2$ population and the averages of parent, check, and $F_2$ plants are in direct agreement with the tolerance tests; that is, resistance is dominant.

If the results from the tolerance tests have been correctly interpreted these data provide sufficient evidence for accepting the single dominant factor hypothesis for resistance.

The assigned genotype of Dobaku is $Grb_1$ $Grb_1$ $grb_2$ $grb_2$ and C.I. 5087 genotype is $grb_1$ $grb_1$ $grb_2$ $grb_2$. Since $grb_2$ is a recessive gene for resistance this would allow C.I. 5087 to express an intermediate type of greenbug resistance which has been reported in a reaction study by Grant (16).

Set III -- Omugi X Tenkow

The graphic presentation of the accumulated rating data shows that the average of the $F_2$ plants is intermediate between the two parents, but approaches the mean of Omugi (Fig. 10). The mean for the $F_2$ plants is 155.6 as compared to 134.0 for Tenkow and 164.0 for Omugi. An accumulated rating value of 151.0 was used as the figure for separating resistant and susceptible $F_2$ plants. Therefore $F_2$ plants with

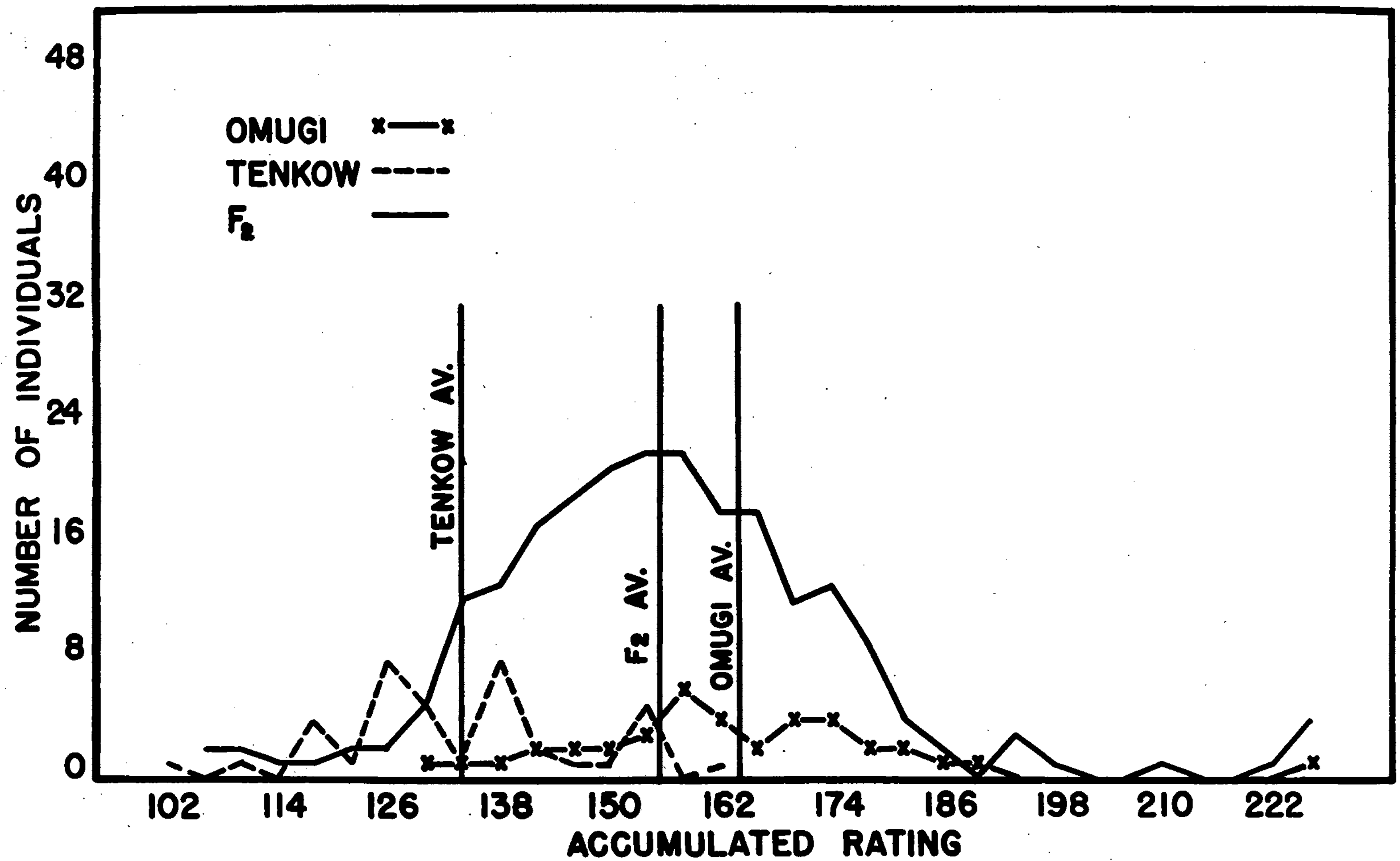


Fig. 10.--Distribution of parent and $F_2$ plants of Omugi x Tenkow by accumulated rating classes when tested under artificial infestation of greenbugs at Stillwater, Oklahoma, 1950-51.

accumulated rating scores of 151.0 and less were classed as susceptible and those with a rating value of more than this value were classed as resistant.

The results for resistance to greenbug attack as measured by the amount of growth test shows a similar trend to that reported for the accumulated rating test (Fig. 11). The $F_2$ plants showed an average increase in height of 13.6 centimeters during the period of infestation. This is 3.4 centimeters more than the Tenkow average of 10.2 and 2.9 less than the Omugi average of 16.5 centimeters. In this test, plants that grew 12 centimeters or less were classified as susceptible and those that grew more than this were classified as resistant.

As was the case with the previous crosses, the preference test in this cross indicates that on the average the $F_2$ plants are less preferred than the susceptible parent, but slightly more preferred than the resistant parent (Fig. 12). The averages were as follows: 32.6 greenbugs per plant for Tenkow, 18.0 for the $F_2$, and the 14.0 for Omugi. Also resistance is dominant.

If the data presented for these tests have been interpreted correctly, a 9:7 ratio of resistant to susceptible plants is indicated. The fact that resistance occurred in nine-sixteenths of the $F_2$ plants suggests that this resistance is obtained only when two independent dominant genes are both present. The observed number of plants for the accumulated rating test is 136:91 and 122:105 for the amount of growth test. The expected numbers for a 9:7 ratio are 128:99. The probability that the ratio hypothesized is correct is 20% to 30% for the accumulated rating test and 30% to 50% for the amount of

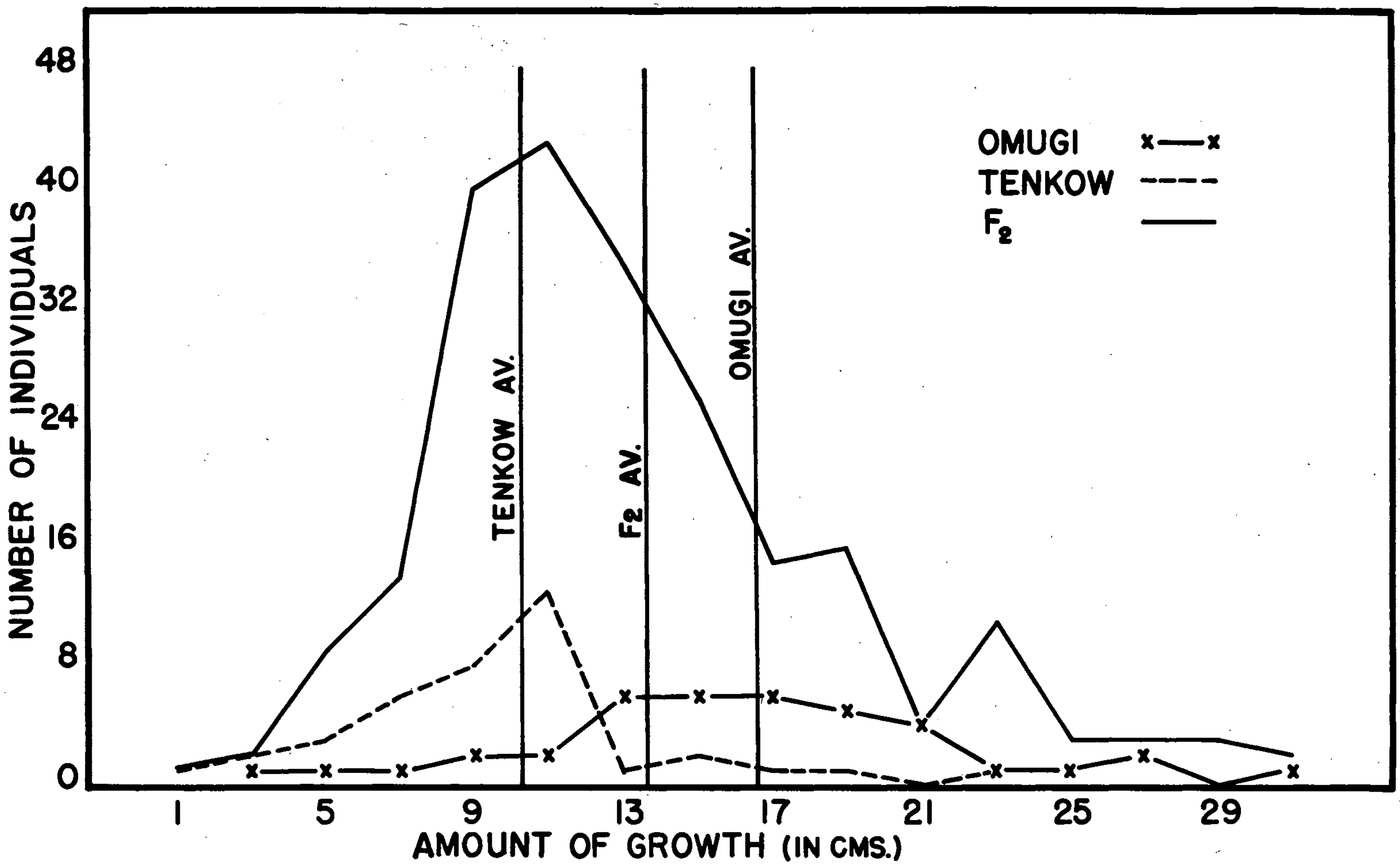


Fig. 11.--Distribution of parent and $F_2$ plants of Omugi x Tenkow by amount of growth classes when tested under artificial infestation of greenbugs at Stillwater, Oklahoma, 1950-51.

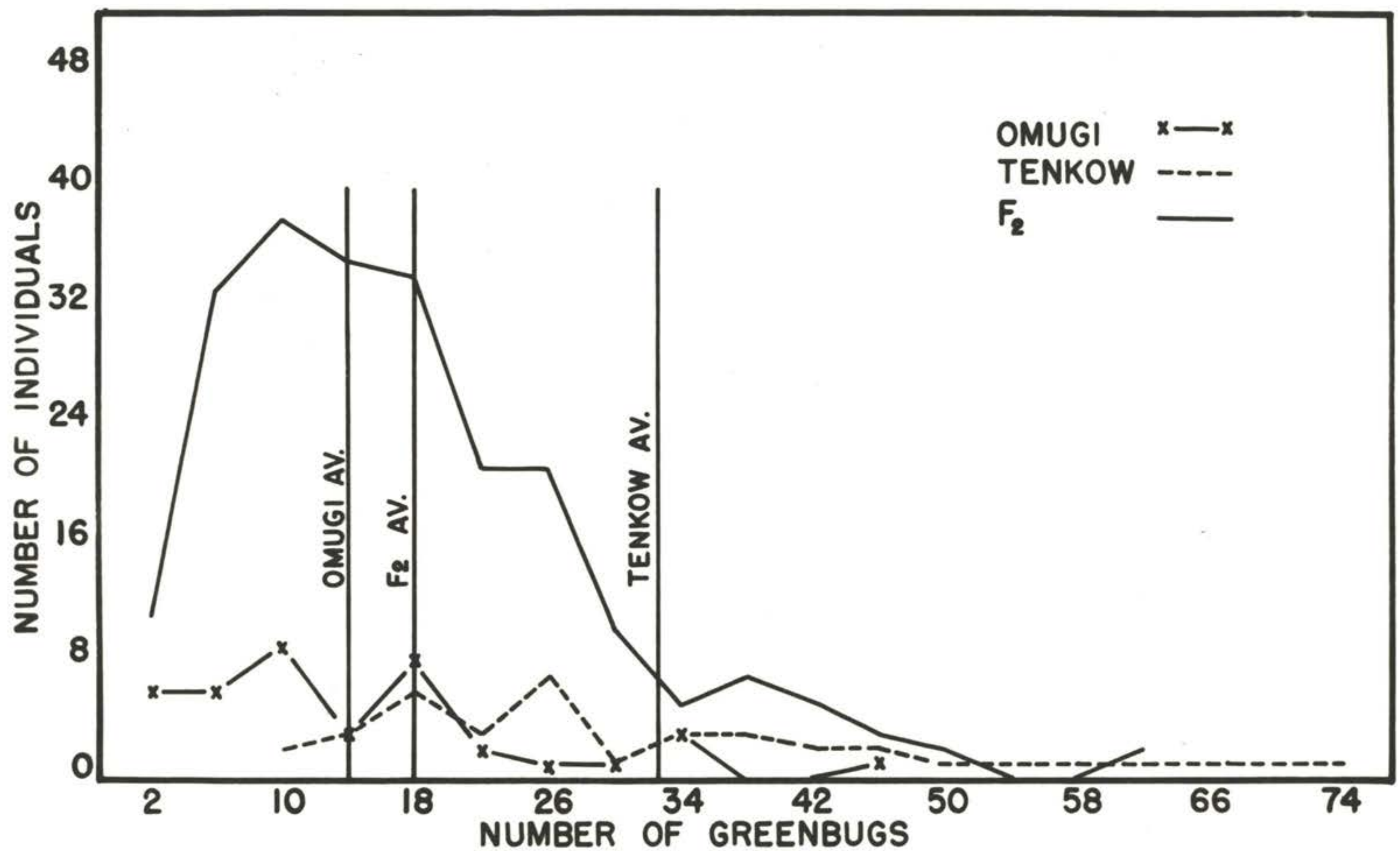


Fig. 12.--Distribution of parent and $F_2$ plants of Omugi x Tenkow by preference of greenbugs when tested under artificial infestation at Stillwater, Oklahoma, 1950-51.

growth test (See Table 5).

The preference test adds further evidence by indicating from the average that resistance is dominant.

According to these results the resistant parent, Omugi, should be of the genotype $Grb_1$ $Grb_1$ $Grb_3$ $Grb_3$ and Tenkow of the genotype $grb_1$ $grb_1$ $grb_3$ $grb_3$.

Set IV --Omugi X Ward

The accumulated rating test for this cross shows a mean rating of 178 for the $F_2$ plants. This indicates that the majority of the $F_2$ plants are highly resistant to greenbug attack since the mean of Omugi is 176 and Ward has an average of only 146 (Fig. 13). The assumption was made for this test that plants with a rating of 162 and less were susceptible and those with higher rates were resistant to greenbug attack.

The average increase in height for the $F_2$ hybrids of this cross as shown in Figure 14 was the same as for the resistant parent, Omugi. Under conditions of artificial greenbug infestation both grew an average of 18 centimeters as compared to 11 centimeters for the Ward parent. Therefore those $F_2$ plants which grew 14 centimeters or less were classed as susceptible and those that grew more than 14 centimeters were classed as resistant (Fig. 14).

The average number of greenbugs per $F_2$ plant was 21.1 (Fig. 15). On the average the $F_2$ plants were less preferred than the resistant parent which had a mean of 27 greenbugs per plant and decidedly less preferred than the Ward parent which had an average infestation of 36 greenbugs per plant. This criterion of measuring greenbug resistance

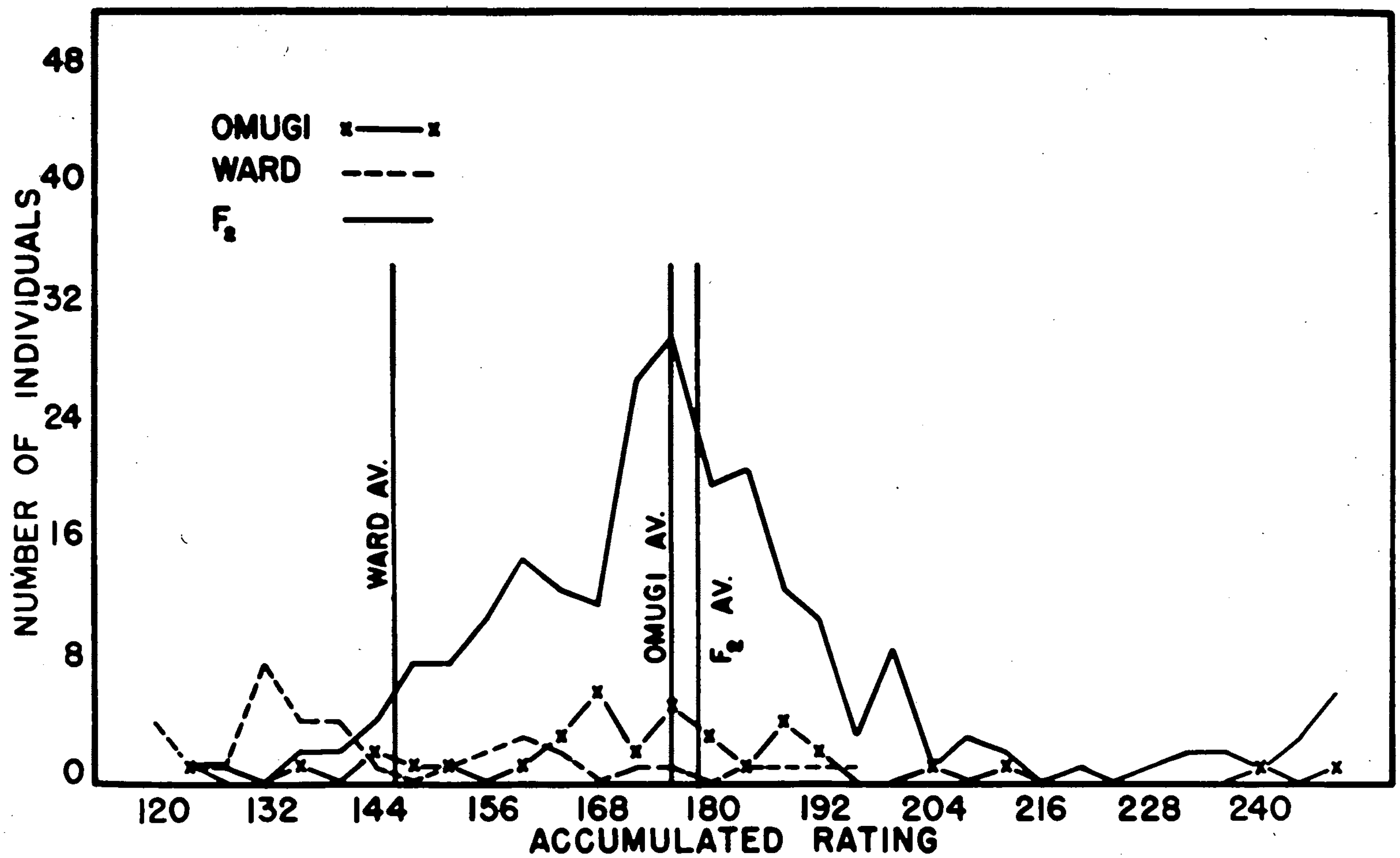


Fig. 13.--Distribution of parent and $F_2$ plants of Omugi x Ward by accumulated rating classes when tested under artificial infestation of greenbugs at Stillwater, Oklahoma, 1950-51.

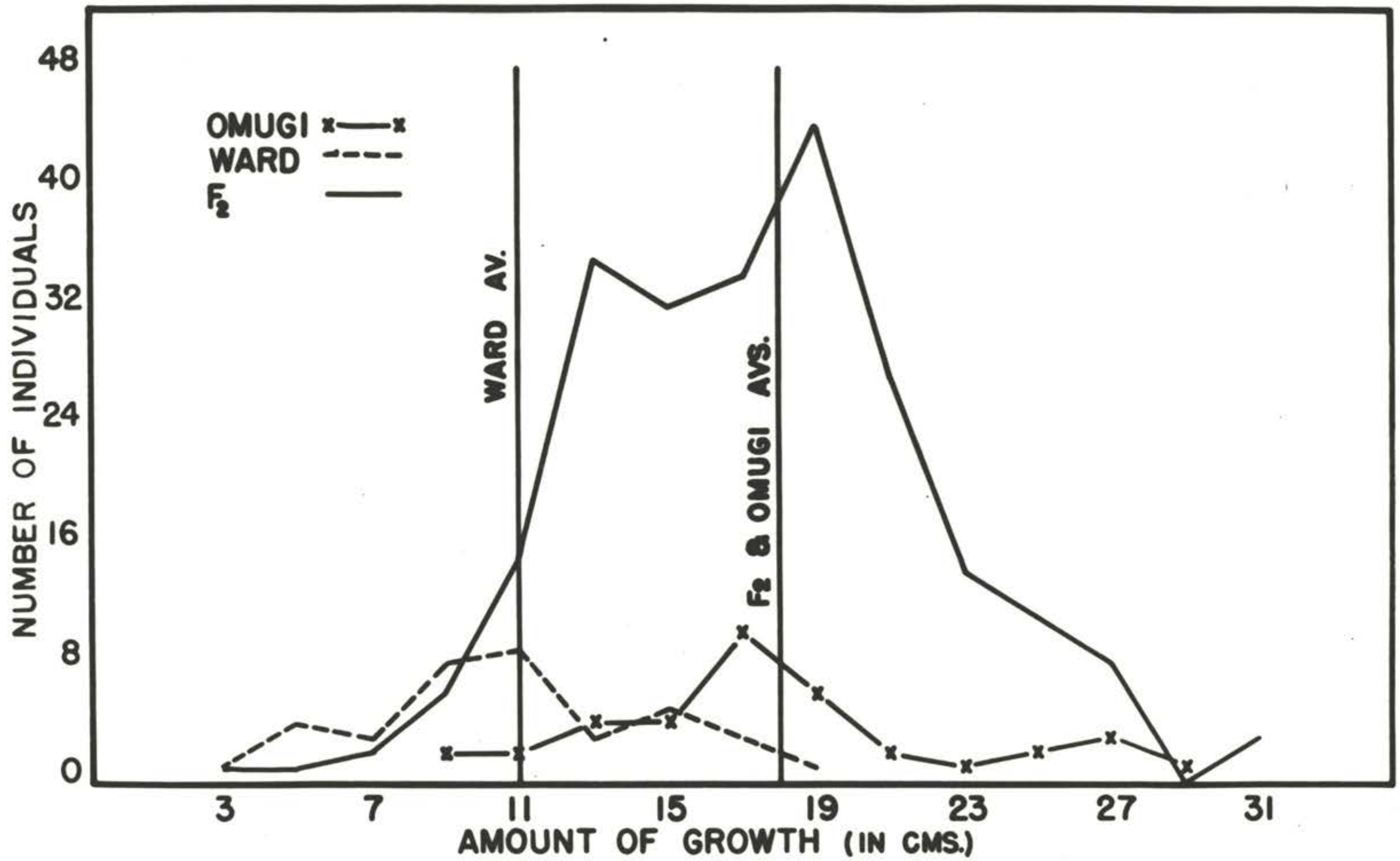


Fig. 14.--Distribution of parent and $F_2$ plants of Omugi x Ward by amount of growth classes when tested under artificial infestation of greenbugs at Stillwater, Oklahoma, 1950-51.

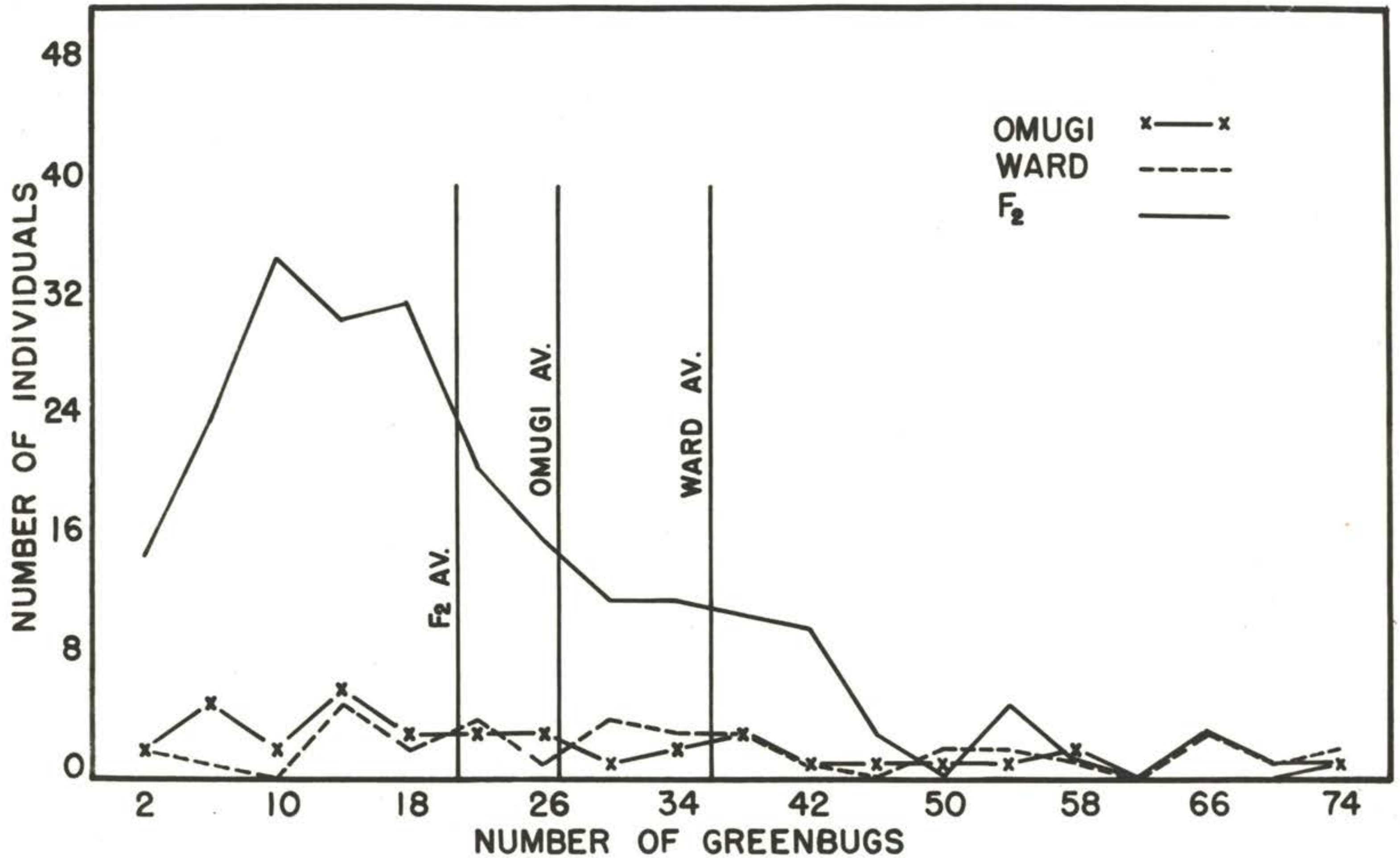


Fig. 15.--Distribution of parent and $F_2$ plants of Omugi x Ward by preference of greenbugs when tested under artificial infestation at Stillwater, Oklahoma, 1950-51.

indicates a very high degree of resistance for the $F_2$ plants.

If the data for the tolerance tests have been used correctly it shows an observed segregation of 181:52 for the accumulated rating test and 173:60 for the amount of growth test. If a ratio of 3 resistant to 1 susceptible is hypothesized the expected numbers would be 175:58. The probability that a 3:1 ratio is correct is 30% to 50% for the accumulated rating test and 70% to 80% for the amount of growth test (See Table 5).

From these data the probable genotype of Omugi would be $Grb_1$ $Grb_1$ and the genotype of Ward would be $grb_1$ $grb_1$.

## DISCUSSION

As shown by the graphs for each of the three methods of measuring resistance of the $F_2$ plants to greenbug attack, resistance is dominant to susceptibility in all four crosses.

Grant (16) found from his reaction studies a very definite difference in the preference of greenbugs for the varieties used as parents and checks in this study. Under the conditions of this experiment the parent and check plants gave similar results in the preference test. A possible explanation for the different results in the present studies might be that the $F_2$ hybrid plants were less preferred than the resistant parent and therefore caused a heavier infestation of greenbugs on the resistant parent than Grant found in his study. Grant used varieties the majority of which were quite susceptible to greenbug attack. In the present studies there appears to be very little correlation between the results obtained from the preference test and those obtained from the accumulated rating and amount of growth tests except that dominance of resistance (presence of fewer greenbugs) is indicated.

The observed difference in these tests also could have entered in at the time the greenbugs were counted since all greenbugs (nymphs and adults) were counted. Perhaps the better method would be the one Dr. R. G. Dahms is using at the present time, that is counting only the original bugs with which the plants were infested and disregarding the new-born nymphs. This appears to be the more desirable method and would give a more valid expression of greenbug preference since the new-born nymphs would probably remain on the same plant on which they were born for several days before moving about.

Since there are no data in this study to differentiate between the dominant gene for resistance which Omugi and Dobaku carry it is assumed that this is one and the same gene, $Grb_1$. Further study is needed to definitely determine whether or not they are the same gene.

Results from Set IV indicated that Omugi has only one dominant gene for resistance. Evidently the $Grb_3$ gene for resistance which was expressed in the Omugi X Tenkow cross is not expressed when Omugi is crossed with Ward. Evidently there is a gene in Ward which is counteracting the second gene for resistance in Omugi. Here, too, further study is needed to definitely determine this aspect.

# SUMMARY

The reaction of barley hybrids to artificially induced greenbug attack was studied under greenhouse conditions at Stillwater, Oklahoma, to determine the mode of inheritance of resistance. Two resistant varieties, Omugi and Dobaku, a semi-resistant variety, C.I. 5087, and two susceptible varieties, Ward and Tenkow, were used as parents. The first two were selected because of their indicated resistance and the latter two are leading varieties in Oklahoma.

The $F_1$ and $F_2$ populations were studied from the three following aspects:

1. Preference of greenbugs for certain barley plants.
2. Tolerance of plants to greenbug attack as measured by the accumulated ratings.
3. Tolerance as measured by the amount of growth.

Major emphasis was placed on the study of the $F_2$ hybrids since the amount of crossed seed available for $F_1$ hybrids was quite limited. In general, the $F_1$ plants were considerably more resistant than the susceptible parent.

The analysis of variance of the parental and check data for the $F_2$ study for tolerance indicated that there was generally a highly significant difference (.01 point) between both varieties and replications. The preference data in general did not indicate a significant difference (.05 point) between replications but did between varieties.

In both preference and tolerance tests, the mean of all $F_2$ plants was closer to the mean of the resistant parent than it was to that of the susceptible parent. According to these results, resistance to greenbugs for the crosses studied appears to be dominant to susceptibility.

For the accumulated rating and amount of growth tests classification of resistant and susceptible plants was based on the point at which the lines representing the distributions of the parents crossed.

The $F_2$ plants were not classified for resistance and susceptibility in the preference test because of the erratic distribution of the parents. Possible explanations are hypothesized.

Chi-square values for goodness of fit to the ratios hypothesized for each cross were calculated for the accumulated rating, and the amount of growth tests. Probabilities were determined. The cross Dobaku X Ward, Set I, showed probabilities for a 13:3 ratio of 30% to 50% for the amount of growth test and 50% to 70% for the accumulated rating test. The symbol Grb is assigned at this time for the gene for greenbug resistance. Dobaku therefore should be of the genotype $Grb_1$ $Grb_1$ $grb_2$ $grb_2$ and Ward of the genotype $grb_1$ $grb_1$ $Grb_2$ $Grb_2$.

According to the data for Set II, Dobaku and C.I. 5087 differ by one dominant gene for resistance. The probabilities that the 3:1 ratio is correct were 50% to 70% for the accumulated rating test and 30% to 50% for the amount of growth test. The genotype of Dobaku as reported in Set I is $Grb_1$ $Grb_1$ $grb_2$ $grb_2$ and C.I. 5087 is $grb_1$ $grb_1$ $grb_2$ $grb_2$. These results are in agreement with information reported by other workers that C.I. 5087 is of a semi-resistant type.

The results from Set III (Omugi X Tenkow) indicate that there are two dominant genes for resistance which have a complementary effect. The accumulated rating and amount of growth tests produced satisfactory evidence that the 9:7 ratio hypothesized is probably correct. The probabilities were 20% to 30% and 30% to 50% respectively. From this evidence the Omugi parent appears to be of the genotype $Grb_1$ $Grb_1$ $Grb_3$ $Grb_3$ and Tenkow of the genotype $grb_1$ $grb_1$ $grb_3$ $grb_3$.

When Omugi was crossed with Ward the $F_2$ population segregated into a 3:1 ratio as indicated in Set IV. Resistance as measured by the accumulated rating and amount of growth tests gave probabilities for a 3:1 ratio of 30% to 50% and 70% to 80% respectively. Therefore, if the data have been interpreted correctly the Omugi parent of this cross would be of the genotype $Grb_1$ $Grb_1$ and Ward would be of the genotype $grb_1$ $grb_1$.

From these studies it is not possible to distinguish between the gene for resistance expressed in Omugi from that which is expressed in Dobaku. For this reason this gene has been designated as $Grb_1$ until further study distinguishes between them.

## LITERATURE CITED


1. Albrecht, H. R. and Chamberlain, T. R. Instability of resistance to aphids of some strains of alfalfa. Jour. Econ. Ent., 34:551-554. 1941.

2. Atkins, I. M. and Dahms, R. G. Reaction of small-grain varieties to greenbug attack. U.S.D.A. Tech. Bul. 901. 1945.

3. Blanchard, R. A. Insect resistance in forage plants. Jour. Amer. Soc. Agron., 35:716-724. 1943.

4. Blanchard, R. A. and Dudley, J. E., Jr. Alfalfa plants resistant to the pea aphid. Jour. Econ. Ent., 27:263-264. 1934.

5. Cartwright, W. B. and Shands, R. G. Resistance to the Hessian fly in crosses of some common spring wheats. Jour. Amer. Soc. Agron., 38:845-847. 1946.

6. Cartwright, W. B. and Wiebe, G. A. Inheritance of resistance to Hessian fly in the wheat crosses Dawson X Poso, and Dawson X Big Club. Jour. Agr. Res., 52:691-695. 1936.

7. Chatters, R. M. and Schlehuber, A. M. Mechanics of feeding of the greenbug (Toxoptera Graminum Rond.) on Hordeum, Avena, and Triticum. Okla. Agr. Exp. Sta. Tech. Bul. T-40. 1951.

8. Dahms, R. G. Preventing greenbug outbreaks. U.S.D.A. Leaf. 309. 1951.

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

10. ____________ and ____________. The effect of fertilizers on chinch bug resistance in sorghums. Jour. Econ. Ent., 33:688-692. 1940.

11. Dahms, R. G. and Martin, J. H. Resistance of $F_1$ sorghum hybrids to the chinch bug. Jour. Amer. Soc. Agron., 32:141-147. 1940.

12. Dahms, R. G., and Painter, R. H.
Rate of reproduction of the pea aphid on different alfalfa plants. Jour. Econ. Ent., 33:482-485. 1940.

13. Dahms, R. G., Snelling, R. O., and Fenton, F. A.
Effect of different varieties of sorghum on the biology of the chinch bug. Jour. Amer. Soc. Agron. 28:160-161. 1936.

14. Emery, W. T.
Temporary immunity in alfalfa ordinarily susceptible to attack by the pea aphid. Jour. Agr. Res., 73:33-43. 1946.

15. Gossard, H. A. and Houser, J. S.
The Hessian fly injury. Jour. Agr. Res., 12:519-527. 1918.

16. Grant, U. J.
The reaction of certain barley varieties to greenbug attack. Unpublished M. S. thesis. Okla. A. & M. College. 1948.

17. Jones, E. T.
Insect resistance in wheat. Jour. Amer. Soc. Agron., 35:695-703. 1943.

18. Jones, L. G., Briggs, F. N. and Blanchard, R. A.
Inheritance of resistance to the pea aphid in alfalfa hybrids. Hilgardia, 20:9-17. 1950.

19. McColloch, J. W. and Salmon, S. C.
Relation of kinds and varieties of grain to Hessian fly injury. Jour. Agr. Res., 12:519-527. 1918.

20. Noble, W. B., Cartwright, W. B. and Suneson, C. A.
Inheritance of resistance to Hessian fly. Jour. Econ. Ent., 33:580-581. 1940.

21. Noble, W. B. and Suneson, C. A.
Differentiation of the two genetic factors for resistance to the Hessian fly in Dawson wheat. Jour. Agr. Res., 67:27-32. 1943.

22. Painter, R. H.
Insect Resistance in Crop Plants. New York: The MacMillian Co., 1951. Page 153.

23. Painter, R. H. and Jones, E. T.
The Hessian fly resistance of Pawnee wheat. Jour. Kans. Ent. Soc., 18:130-149. 1945.

24. Painter, R. H., Jones, E. T., Johnston, C. O. and Parker, J. H.
Transference of Hessian fly resistance and other characteristics of Marquillo spring wheat to winter wheat. Kans. Exp. Sta. Tech. Bul. 49. 1940.

25. Painter, R. H., Salmon, S. C. and Parker, J. H.
Resistance of varieties of winter wheat to Hessian fly. Kans. Agr. Exp. Sta. Tech. Bul. 27. 1931.

26. Parker, J. H. and Painter, R. H.
Insect resistance in crop plants. Proc. 6th Internatl. Genetics Cong., Ithaca, N. Y. (1926), 2:150-152. 1932.

27. Snelling, R. O., Painter, R. H., Parker, J. H. and Osborn, W. M.
Resistance of sorghums to the chinch bug. U.S.D.A. Tech. Bul. 585. 1937.

28. Suneson, C. A. and Noble, W. B.
Further differentiation of genetic factors in wheat for resistance to the Hessian fly. U.S.D.A. Tech. Bul. 1004. 1950.

29. Wadley, F. M.
Ecology of <u>Toxoptera graminum</u> especially as to factors affecting importance in the northern United States. Ent. Soc. Amer. Ann., 24:325-395. 1931.

30. Walton, W. R.
The greenbug or spring grain aphis: How to prevent its periodical outbreaks. U.S.D.A. Farmers Bul. 1217. 1921.

A P P E N D I X

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Appendix Table 1.--Daily Record for Pot 33, Set III, greenhouse tests, Stillwater, Oklahoma, 1950-51.

| Plant No. | Variety or Cross | C.I. No. | Jan. | | | | Total Grb. | Feb. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 28 | 29 | 30 | 31 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | Tenkow | 646 | 9/0 | 12/0 | 25/0 | 30/0 | /1 76 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 |
| 2 | Omugi X Tenkow | | 5/0 | 7/0 | 6/0 | 5/0 | 23 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | Omugi X Tenkow | | 1/0 | 1/0 | 1/0 | 1/0 | 4 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 | Omugi X Tenkow | | 1/0 | 0/0 | 0/0 | 0/0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 5 | Omugi X Tenkow | | 1/0 | 2/0 | 6/0 | 8/0 | 17 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | Omugi X Tenkow | | 3/0 | 5/0 | 4/0 | 5/0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 7 | Omugi X Tenkow | | 2/0 | 4/0 | 4/0 | 6/0 | 16 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | Omugi | 5144 | 2/0 | 2/0 | 2/0 | 4/0 | 10 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |

Remarks:

Appendix Table 1.--Continued.

| Plant No. | Variety or Cross | C.I. No. | Feb. 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | Ht. in Cm. Start | End | Amt. of Growth | Total No. Days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tenkow | 646 | 4 /2 | 5 | | | | | | | | | | 13 | 18 | 5 | 17 |
| 2 | Omugi X Tenkow | | 2 | 2 | 3 | 4 | 5 | | | | | | | 15 | 23½ | 8½ | 20 |
| 3 | Omugi X Tenkow | | 1 | 2 | 2 | 3 | 4 | 4 | 5 | | | | | 13 | 28 | 15 | 22 |
| 4 | Omugi X Tenkow | | 1 | 2 | 2 | 3 | 3 | 4 | 5 | | | | | 17 | 31½ | 14½ | 22 |
| 5 | Omugi X Tenkow | | 2 | 2 | 3 | 4 | 5 | | | | | | | 18½ | 32½ | 14 | 20 |
| 6 | Omugi X Tenkow | | 1 | 2 | 2 | 3 | 4 | 5 | | | | | | 15 | 26½ | 11½ | 21 |
| 7 | Omugi X Tenkow | | 1 | 2 | 2 | 3 | 4 | 5 | | | | | | 18 | 32½ | 14 | 21 |
| 8 | Omugi | 5144 | 1 | 2 | 2 | 2 | 3 | 4 | 5 | | | | | 17 | 33½ | 16½ | 22 |

Remarks:

/1 Numbers in smaller squares for first 4 days denote number of aphids on each plant.

/2 Numbers denote the daily rating for estimated damage.

Appendix Table 2.--Tolerance of parent, check and $F_2$ plants of four barley crosses to artificially induced greenbug attack as measured by the accumulated rating test at Stillwater, Oklahoma, 1950-51.

| Variety or Cross | Accumulated Rating* | | | | | | | | | | | | | | | | | | | | | | | Total Plants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 54 | 58 | 62 | 66 | 70 | 74 | 78 | 82 | 86 | 90 | 94 | 98 | 102 | 106 | 110 | 114 | 118 | 122 | 126 | 130 | 134 | 138 | |
| **Set I - Dobaku X Ward** | | | | | | | | | | | | | | | | | | | | | | | | |
| Omugi | - | - | - | - | - | - | - | - | - | - | - | - | (40)** | | - | - | - | - | - | - | - | - | - | 40 |
| Dobaku | - | - | - | - | - | - | - | - | - | 5 | - | 10 | 5 | 3 | 4 | 6 | 2 | 2 | 2 | 1 | - | - | - | 40 |
| Ward | 2 | 1 | 1 | 3 | 2 | 2 | 4 | 2 | 4 | 3 | 4 | 4 | 2 | 4 | - | 1 | - | - | 1 | - | - | - | - | 40 |
| $F_2$ | - | 1 | - | - | 3 | 2 | 3 | 2 | 5 | 13 | 14 | 34 | 26 | 27 | 26 | 14 | 12 | 9 | 3 | 3 | 1 | - | 1 | 199 |
| **Set II - Dobaku X C.I. 5087** | | | | | | | | | | | | | | | | | | | | | | | | |
| Omugi | - | - | - | - | - | - | - | - | - | - | - | - | (40)** | | - | - | - | - | - | - | - | - | - | 40 |
| Dobaku | - | - | - | - | - | - | - | - | - | - | 1 | 4 | 10 | 6 | 10 | 5 | 2 | - | - | - | 1 | - | - | 39 |
| C.I. 5087 | - | 1 | - | - | - | - | 1 | 1 | 1 | 6 | 10 | 6 | 8 | 2 | 3 | - | - | - | - | - | - | - | - | 39 |
| $F_2$ | - | 1 | - | - | - | 1 | 1 | - | 3 | 8 | 14 | 27 | 40 | 41 | 39 | 13 | 9 | 1 | 1 | 1 | - | - | - | 200 |

Appendix Table 2.--Continued.

| Variety or Cross | Accumulated Rating* 102 | 106 | 110 | 114 | 118 | 122 | 126 | 130 | 134 | 138 | 142 | 146 | 150 | 154 | 158 | 162 | 166 | 170 | 174 | 178 | 182 | 186 | 190 | 194 | 198 | 202 | 206 | 210 | 214 | 218 | 222 | 226 | Total Plants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Set III - Omugi X Tenkow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Omugi | - | - | - | - | - | - | - | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 6 | 4 | 2 | 4 | 4 | 2 | 2 | 1 | 1 | - | - | - | - | - | - | - | - | 1 | 39 |
| Tenkow | 1 | - | 1 | - | 4 | 1 | 8 | 5 | 1 | 8 | 2 | 1 | 1 | 5 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 39 |
| $F_2$ | - | 2 | 2 | 1 | 1 | 2 | 2 | 5 | 12 | 13 | 17 | 19 | 21 | 22 | 22 | 18 | 18 | 12 | 13 | 9 | 4 | 2 | - | 3 | 1 | - | - | 1 | - | - | 1 | 4 | 227 |

| Variety or Cross | Accumulated Rating* 120 | 124 | 128 | 132 | 136 | 140 | 144 | 148 | 152 | 156 | 160 | 164 | 168 | 172 | 176 | 180 | 184 | 188 | 192 | 196 | 200 | 204 | 208 | 212 | 216 | 220 | 224 | 228 | 232 | 236 | 240 | 244 | 248 | Total Plants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Set IV - Omugi X Ward | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Omugi | - | 1 | - | - | 1 | - | 2 | 1 | 1 | - | 1 | 3 | 6 | 2 | 5 | 3 | 1 | 4 | 2 | - | - | 1 | - | 1 | - | - | - | - | - | - | 1 | - | 1 | 37 |
| Ward | 4 | 1 | 1 | 8 | 4 | 4 | 1 | - | 1 | 2 | 3 | 2 | - | 1 | 1 | - | 1 | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 37 |
| $F_2$ | - | 1 | 1 | - | 2 | 2 | 4 | 8 | 8 | 11 | 15 | 13 | 12 | 27 | 30 | 20 | 21 | 13 | 11 | 3 | 9 | 1 | 3 | 2 | - | 1 | - | 1 | 2 | 2 | 1 | 3 | 6 | 233 |

*See Material and Methods for method of calculation.

**In percent of Omugi.

Appendix Table 3.--Tolerance of parent, check, and $F_2$ plants of four barley crosses to artificially induced greenbug attack as measured by the amount of growth test at Stillwater, Oklahoma, 1950-51.

| Variety or Cross | Amount of Growth in % of Omugi* | | | | | | | | | | | | | | | | | | | | | | | | | | | Total Plants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15 | 25 | 35 | 45 | 55 | 65 | 75 | 85 | 95 | 105 | 115 | 125 | 135 | 145 | 155 | 165 | 175 | 185 | 195 | 205 | 215 | 225 | 235 | 245 | 255 | 265 | 275 | |
| **Set I - Dobaku X Ward** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Omugi | - | - | - | - | - | - | - | - | (40) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 40 |
| Dobaku | - | - | - | - | - | 1 | - | 5 | 8 | 9 | 3 | 3 | 6 | 1 | 1 | 1 | 1 | - | - | - | - | - | - | - | 1 | - | - | 40 |
| Ward | 2 | 2 | 4 | 3 | 7 | 4 | 4 | 5 | 4 | - | 1 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 40 |
| $F_2$ | - | - | - | 1 | 1 | 7 | 14 | 19 | 31 | 39 | 20 | 19 | 17 | 8 | 2 | 5 | 5 | 6 | 2 | - | - | - | - | - | 2 | 1 | - | 199 |
| **Set II - Dobaku X C.I. 5087** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Omugi | - | - | - | - | - | - | - | - | (40) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 40 |
| Dobaku | - | - | - | - | - | 1 | 1 | 4 | 5 | 2 | 4 | 9 | 2 | 3 | 2 | 1 | - | 3 | - | - | - | 1 | - | - | 1 | - | - | 39 |
| C.I. 5087 | 1 | 1 | 1 | 1 | 5 | 10 | 8 | 3 | 4 | - | 1 | 1 | - | - | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | 39 |
| $F_2$ | - | - | - | 7 | 9 | 9 | 20 | 27 | 32 | 20 | 24 | 19 | 8 | 7 | - | 2 | 2 | 2 | 1 | 1 | 3 | 6 | - | - | - | - | 1 | 200 |

Appendix Table 3.--Continued.

| Variety or Cross | Amount of Growth in Cm.** | | | | | | | | | | | | | | | | Total Plants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | |
| Set III - Omugi X Tenkow | | | | | | | | | | | | | | | | | |
| Omugi | - | 1 | 1 | 1 | 2 | 2 | 6 | 6 | 6 | 5 | 4 | 1 | 1 | 2 | - | 1 | 39 |
| Tenkow | 1 | 2 | 3 | 6 | 8 | 13 | 1 | 2 | 1 | 1 | - | 1 | - | - | - | - | 39 |
| $F_2$ | 1 | 2 | 9 | 14 | 40 | 43 | 35 | 26 | 15 | 16 | 4 | 11 | 3 | 3 | 3 | 2 | 227 |
| Set IV - Omugi X Ward | | | | | | | | | | | | | | | | | |
| Omugi | - | - | - | - | 2 | 2 | 4 | 4 | 10 | 6 | 2 | 1 | 2 | 3 | 1 | - | 37 |
| Ward | - | 1 | 4 | 3 | 8 | 9 | 3 | 5 | 3 | 1 | - | - | - | - | - | - | 37 |
| $F_2$ | - | 1 | 1 | 2 | 6 | 15 | 35 | 32 | 34 | 44 | 27 | 14 | 11 | 8 | - | 3 | 233 |

*Figured in % of the Omugi check in the same pot.

**Amount of growth made during period of infestation.

Appendix Table 4.--Preference of greenbugs for parent, check, and $F_2$ plants during the first four days of artificial infestation at Stillwater, Oklahoma, 1950-51.

| Variety or Cross | Total No. of Greenbugs per plant* | | | | | | | | | | | | | | | | | | | | | | | | | Total Plants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 6 | 10 | 14 | 18 | 22 | 26 | 30 | 34 | 38 | 42 | 46 | 50 | 54 | 58 | 62 | 66 | 70 | 74 | 78 | 82 | 86 | 90 | 94 | 98 | |
| | | | | | | | | | | | | Set I - Dobaku x Ward | | | | | | | | | | | | | | |
| Omugi | 5 | 2 | 4 | 8 | 5 | 1 | 4 | - | 2 | 3 | - | 1 | - | 4 | - | 1 | | | | | | | | | | 40 |
| Dobaku | 5 | 4 | 2 | 8 | 3 | 3 | 2 | 3 | 2 | 1 | - | 3 | - | 2 | 1 | - | - | - | 1 | | | | | | | 40 |
| Ward | 1 | - | 1 | 5 | 1 | 3 | 4 | 6 | 3 | 3 | - | 3 | 1 | 1 | - | 1 | - | 1 | - | 1 | - | - | 2 | 1 | 2 | 40 |
| $F_2$ | 8 | 17 | 21 | 17 | 16 | 19 | 15 | 9 | 11 | 12 | 10 | 7 | 7 | 5 | 2 | 5 | 5 | - | 2 | 2 | 2 | 2 | 1 | 1 | 3 | 199 |
| | | | | | | | | | | | | Set II - Dobaku x C.I. 5087 | | | | | | | | | | | | | | |
| Omugi | 3 | 9 | 10 | 3 | 4 | 2 | 2 | 3 | 1 | 1 | - | - | 1 | 1 | | | | | | | | | | | | 40 |
| Dobaku | 2 | 9 | 7 | 7 | 2 | 4 | 5 | 3 | | | | | | | | | | | | | | | | | | 39 |
| C.I. 5087 | 2 | 5 | 6 | 6 | 3 | 1 | 2 | 1 | 4 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | 39 |
| $F_2$ | 13 | 28 | 29 | 40 | 29 | 12 | 15 | 5 | 10 | 6 | 4 | 3 | 2 | 3 | - | - | 1 | | | | | | | | | 200 |
| | | | | | | | | | | | | Set III - Omugi x Tenkow | | | | | | | | | | | | | | |
| Omugi | 6 | 6 | 9 | 3 | 8 | 2 | 1 | 1 | 3 | - | - | 1 | | | | | | | | | | | | | | 39 |
| Tenkow | - | - | 2 | 3 | 6 | 3 | 7 | 1 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | 39 |
| $F_2$ | 11 | 33 | 38 | 35 | 34 | 21 | 21 | 10 | 5 | 7 | 5 | 3 | 2 | - | - | 2 | | | | | | | | | | 227 |
| | | | | | | | | | | | | Set IV - Omugi x Ward | | | | | | | | | | | | | | |
| Omugi | 2 | 5 | 2 | 6 | 3 | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | - | - | - | 1 | | | | | | | 37 |
| Ward | 2 | 1 | - | 5 | 2 | 4 | 1 | 4 | 3 | 3 | 1 | - | 2 | 2 | 1 | - | 3 | 1 | 2 | | | | | | | 37 |
| $F_2$ | 15 | 24 | 35 | 31 | 32 | 21 | 16 | 12 | 12 | 11 | 10 | 3 | - | 5 | 1 | - | 3 | 1 | 1 | | | | | | | 233 |

*Refers to the total number of greenbugs counted on each plant for the first four days after infestation.

THESIS TITLE: INHERITANCE OF RESISTANCE TO THE GREENBUG (<u>TOXOPTERA GRAMINUM</u> ROND.) IN WINTER BARLEY HYBRIDS

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THESIS ADVISER: DR. A. M. SCHLEHUBER

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