RESISTANCE OF WINTER BARLEY VARIETIES AND SELECTIONS TO

A BIOTYPE OF THE GREENBUG, *SCHIZAPHIS GRAMINUM* (ROND.)

By

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PREFACE

The unusual injury to greenbug resistant small grains by a greenbug biotype interested the author who had previously worked with the two strains of the greenbug in a study of the effects of various temperatures on their fecundity. Mr. C. F. Henderson suggested the screening of the World Collection of winter barley varieties to find differential resistance against the two strains of the greenbug for future breeding work. Use of resistant varieties against small grain insect pests has proved to be an economical method of pest control.

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INTRODUCTION

The greenbug, <u>Schizaphis</u> <u>graminum</u> (Rond.), is a major economic pest of small grains in the United States. Barley is one of its favored hosts. Cultural and biological control methods have a limited role, and chemical control is too costly for a low profit crop such as barley. Use of resistant varieties would be very satisfactory for areas of frequent and heavy greenbug infestations. Use of resistant varieties of small grains against other small grain pests have proved to be an effective control at no extra cost to the farmers.

Physiological characters related to insect nutrition generally are the basis of resistance, and they are subject to mutation, laws of inheritance, and natural selection.

Biotypes with mutational characteristics could affect the permanence of resistance as an insect-control measure, should they become dominant in an area. The possibilities do exist as seen in the biotypes of Hessian fly (Painter 33, 34).

Development of insect biotypes capable of destroying resistant varieties could prove to be a major hazard. Laboratory experiments have indicated that varying levels of resistance exist against different species of aphids. Such findings suggested the possibility of screening the World Collection of winter barley for resistant lines to be used against the greenbug and its biotypes.

In Oklahoma evaluation and breeding of resistant small grain varieties has continued since 1947 (Dahms et al., 17; Wood, 57). A greenbug biotype capable of destroying the resistant wheat Dickinson Sel. 28-A was discovered in the greenhouse cultures at Stillwater, Oklahoma and reported by Wood (58).

Screening the World Collection of barley varieties for new sources of germ plasm with resistance against the greenbug biotype was undertaken.

REVIEW OF LITERATURE

The insect commonly known as the greenbug, *Schizaphis graminum* (Rond.), belongs to the order of Homoptera, family Aphididae. It was first described in 1852 as *Aphis graminum* by C. Rondani of Italy (43), and later redescribed in 1863 and placed under the genus *Toxoptera* by Passerini (39). Börner (6) split this genus into two groups, using *Toxoptera graminum* (Rond.) as genotype for his new genus *Schizaphis*. In 1963 Russel (44) accepted the usage of *Schizaphis*. The earliest record of this insect in the United States was reported by Pergande (41) in 1882.

This aphid is widely distributed in North, Central and South America, Europe, Asia and Africa, causing most damage in Southwestern United States, Italy, Hungary, Southern Russia and South Africa.

The food plants of the greenbug are members of the grass family (Gramineae), and are described by Patch (40), Dahms et al. (16), and Daniels et al. (18).

Descriptions of the earliest severe outbreaks of the greenbug are given by Webster and Phillips (54), Kelly (25), and Ainslie (1). More recently Dahms et al. (17) stated that there have been 15 major outbreaks, the most serious occurring in 1907, 1942, 1950, 1951. Arkansas, Illinois, Kansas, Minnesota, Missouri, Oklahoma and Texas have suffered heavy losses due to these outbreaks.

The greenbug does much more injury in proportion to its numbers than any other grain aphid. Webster (53) considered the severe damage caused by a few greenbugs to be a pathological condition associated with the aphid. Wadley (49) suggested that the injury to the plants was due to a chlorophyll-destroying enzyme injected into the cells, rather than the extraction of plant juices.

Before the advent of organic insecticides, Hunter (24), Webster and Phillips (54), Bilsing (5), and Whitehead and Fenton (55) advised cultural measures such as crop rotation, burning of the fall infested areas, and destruction of volunteer crops, as control measures.

A hymenopteran, Aphidius testaceipes (Cress.), was first described by Cresson in 1879 (12), as a parasite of the "wheat aphis". Hunter (24) was the first to try this parasite for the biological control of the greenbug. Webster and Phillips (54), Dahms (15) and Wood (56) studied the relationship of temperature to activity of the parasite and pointed to its limited activity at temperatures below 56°F, whereas greenbug fecundity continued at 40°F, rendering the parasite ineffective.

Effective greenbug control through the use of insecticides began in 1949 with the advent of organic phosphates. In addition to the high cost the extensive use of the widely toxic synthetic insecticides is now associated with the problems of insecticide resistance, secondary pest outbreaks and disruption of the arthropod ecosystem (Bosch and Stern, 7).

Because of the failure of cultural, biological, and chemical control measures against the greenbug on small grains, it was necessary to search for other control methods.

The development and use of plants with resistance to insects, as was done with Hessian fly resistance in wheats, offers promise of effective and economical control.

Resistance of plants to insect damage has been known for over 150 years. George Lindley in 1831 reported an apple variety with resistance to the woolly apple aphid, Eriosoma lanigerum (Hausm.) (Painter, 36). Outstanding success was achieved against the grape-phylloxera Phylloxera vitifoliae (Fitch.) in 1869 by using American resistant grape vine stock, and according to L. O. Howard the French wine industry was saved from total disaster (Snelling, 47).

The first reviews classifying the causes of resistance to insects were made by Wardle and Buckle (52), Mumford (32), and Snelling (47), who also mentioned insect resistance in over 100 plant species. More reviews of the economic value and biological significance of insect resistance in plants were discussed by Painter (35,36,38). He mentioned that 52 insect-crop relationships for 20 crops were under study in the United States in 1957, and 38 varieties of 9 different crops with resistance to 19 insects were known.

Differences in the reaction of wheats to the injury by greenbugs were observed first by Wadley (50). Fenton and Fisher (19), recorded barley as being the preferred host, followed by oats and wheats. Atkins and Dahms (2) studied the reaction of wheat, barley and oat varieties to the greenbug during the 1942 outbreak in the nurseries at Denton and Chillicothe, Texas and at Lawton, Oklahoma. They found several oriental varieties of barley with high resistance to attack while others were killed. They also suggested the screening of the World Collection of small grains for resistant germ plasm. Walton (51) reported a difference in the reaction of barley varieties to greenbug attack and a correlation between plant vigor and degree of injury.

In 1955 Dahms et al. (17) screened several hundred varieties and hybrids of small grains in the greenhouse and found many barley varieties with a high degree of resistance. Painter and Peters (37) reported 2000 varieties of wheat to be more susceptible than Pawnee and only 4 per cent to have some resistance. Wood (57) in a study of 4600 wheat lines, found 19 varieties with a high degree of resistance. Chada et al. (10) screened 1230 winter type world collection barley varieties and found a number of them more resistant than the resistant check, Omugi barley.

Much research has been done as to the nature of plant resistance to insects. Morphological and physiological characteristics have been considered. Chatters and Schlehuber (11) associated leaf thickness with resistance in barley, but suggested that resistance is the expression of physiological differences. Maxwell and Painter (28, 29, 30) were the first to report that auxins might be the basis of the tolerance component of greenbug resistance. Beck (3) considered feeding stimulants and deterrents as influencing the biology of the insect on the host plants, including the manifestation of plant resistance.

Despite the complexity of the causes of resistance, it was considered an important discovery when greenbug resistant germ-plasm was discovered in Omugi by Dahms et al. (17) and later by Gardenhire and Chada (20). The later workers found resistance to be conditioned by a single dominant gene that could be transferred to adapted varieties.

THE BIOTYPE OF THE GREENBUG

As early as 1864 Walsh suggested that variations in plant populations are significant in relation to insect attack, and that biological races of an insect associated with different food plants must exist

(Craighead, 13). Other workers (Thorpe, 48; Hayes, 23; and Smith, 45) pointed to the interactions of host plants and associated biological strains of insects, and to their practical significance in applied entomology.

The first study of biotypes of the Hessian fly in connection with insect resistance was done by Painter (33) and Painter et al. (34).

In view of the possibility of developing greenbug biotypes capable of destroying present resistant varieties, Dahms (14) studied the comparative tolerance of small grains to greenbugs from Oklahoma and Mississippi but found no differences in reaction. However, Wood (58) observed the presence of a greenbug strain damaging resistant Dickinson Sel. 28-A wheat in the greenhouse cultures at Stillwater, Oklahoma. Tests proved the "Greenhouse Strain" to be a biotype distinguishable from the "normal field strain" only through the reaction of resistant wheat lines to the feeding of each strain. The biotype was found to be much more injurious, and heavier and larger in size than the field strain. When reared on Sel. 28-A for 8 generations, the field strain became stunted and its reproductive capacity was decreased; whereas, the greenhouse strain performed normally.

Temperature also influences expression of resistance. The author, worked with Singh (46) on the effects of various temperatures on the two greenbug strains on Sel. 28-A. The greenhouse strain showed the highest fecundity, producing an average of 2.45 nymphs at 75°F, the optimum temperature for oviposition for this strain, as compared to 1.0 nymph at 60°F, the optimum temperature for the field strain. This work indicated that Sel. 28-A was not resistant to the greenhouse strain.

The evolution of biotypes and their success with resistant varieties has been explained by several workers. Painter (36) stated that the biological strains, capable of infesting or damaging resistant plants are basically the result of individual genes or groups of genes. Such genes, especially those involving general vigor, are part of the concealed variability carried by the plant and animal species and are selected as survivors from particular rigorous situations. Such situations often result in a high mortality, with a few individuals which are less affected by the adverse conditions surviving out of a population. These are characteristics that show the presence of biological strains. The author and co-workers theorize that the biotype under study developed from field strain greenbug cultures exposed to high greenhouse temperatures during summer.

More recently workers have turned their attention to the chemical basis of resistance. Beck (3, 4), Kennedy (26), and Maxwell and Painter (28, 29, 30) considered some physiological differences, based on substances which merely inhibit attack in the biotype and plant varieties. This makes it impossible for the insect to utilize an otherwise perfectly suitable plant as food. Kennedy (26) in an attempt to explain the breakdown of such resistance by a biotype, stated that "the pest itself can be expected to develop 'resistance': with the appearance of a new strain which 'requires the former repellent (now attractant) stimulus to induce feeding'------ exactly as Lipke and Fraenkel (27) suppose host specificity to have evolved in the past".

Workers who have encountered biotypes in studies of insect resistance in plants (Painter, 33; Harrington, 21; Dahms, 14; Cartwright and Noble, 8) have varying opinions regarding their development. Painter (33) following the discovery of Hessian fly strains damaging resistant wheats, stated that two solutions are possible: to evolve and use resistant varieties which may be used alternately for periods of years in a given region, or attempt to synthesize new resistant varieties through hybridization and selection out of several wheat varieties.

Pesho et al. (42), working with a biotype of the spotted alfalfa aphid on a resistant Moapa clone, stated that not much damage will be encountered unless the biotype becomes dominant in the insect population of the area.

In this instance the greenhouse strain seems adapted to the particular genetic make-up of the resistant wheat lines on which it successfully feeds. Painter (36) thought the "Ill No.1 W38 strain of Hessian fly, is adjusted in some way to the particular conditions resulting from the presence of a particular gene (H_3) in the plant. In this case certain elements of the insect physiology must fit specific elements of the plant physiology as a key fits a lock".

Biological races such as the greenhouse strain capable of feeding on resistant varieties could also evolve in the natural insect populations in the fields and affect the expression and permanence of resistance thus becoming a major hazard to resistant varieties which generally involve many years of screening and breeding work. Painter (36) considered a change in the genes responsible for resistance or a combination of several genetic factors to form a valid defense against biological strains.

Screening of the World Collection and 55 commercially adapted barley varieties was undertaken with the aim of finding germ plasm which might possess a different genetic factor for resistance towards the greenhouse strain, and which might be used in future breeding work, to augment the present resistance to the field strain.

MATERIALS AND METHODS

Screening small grain varieties for greenbug resistance in the greenhouse by the seedling method has been found satisfactory by many workers. Painter (36), Dahms et al. (17), Chada et al. (10) and Wood (57) observed that highly resistant lines were capable of withstanding greenbug attack in the early seedling stage making it possible to infest the plants at emergence and thus to accelerate the screening process.

The screening tests for the present study were conducted in the greenhouse following a technique described by Wood (59) that simulates infestation under field conditions (Figure 1).

The varieties were rated for injury when plants of the susceptible check were close to the rating of 5 (beyond recovery). This rating system, described by Dahms et al. (17), measures tolerance according to the estimated percentage of leaf area damaged:

Injury Rating	Percent Damage
0	0-10
1	11-20
2	21-40
3	41-60
4	61-80
5	Beyond recovery

Tests with the greenhouse strain were made on 1295 winter barley varieties obtained from the Crops Research Division, U. S. Department of Agriculture. Tests were also conducted on these same varieties in another greenhouse using the field strain during the winter of 1963-64. The first 400 varieties were planted on January 10, 1964, and the seedlings infested at emergence on the 4th day. The injury ratings were begun on Jan. 21, when the susceptible check Dickinson Sel. 28-A wheat showed more than 10% injury. A second rating was made 14 days after infestation and the final rating was made after 21 days. On February 4, when Sel. 28-A had a rating of 5, the test varieties could be classified into resistant and susceptible categories. Three ratings were made at weekly intervals to determine tolerance according to the estimated percentage of leaf area damaged.

During the second test, parasites were encountered on test flats and in the culture pots due to a warming trend in the weather. This problem also delayed the planting of the third test thus delaying the screening of the remaining varieties. This resulted in some variation in the injury ratings, as it was evident that the temperature has much influence on the expression of resistance. The varieties showed early damage and the final rating was made within 17 days.

Cultures of the greenhouse strain were maintained on the susceptible Rogers barley planted in 6 inch pots covered with cylinderical plastic cages to prevent premature infestation of the emerging seedlings. After 14 days the culture plants were infested with approximately 100 greenbugs from the pure culture maintained and checked periodically for reaction to Sel. 28-A wheat which possessed a high degree of resistance to the field strain of the greenbug. In 10 to 14 days cultures were ready for use.

Test varieties were planted in wooden cypress flats 21 x 17 x 4 inches in size. The seeds were placed in 10 rows at uniform depth.

Fifteen seeds of each variety were placed in a row and thinned to 10 plants upon emergence. The fifth and sixth rows were seeded to Sel. 28-A the susceptible check, and Omugi barley the resistant check. All the rows were staked and labelled.

Upon emergence the plants were infested by uniformly sprinkling about 2000 greenbugs on each flat.

Plants that rated 3 or below were considered resistant. Since Omugi, the resistant check, had an average injury rating of approximately 2, a large number of susceptible varieties were eliminated from the second test.

During the second screening test, in late fall, the aphids were parasitized by Aphidius testaceipes (Cress.). Parasitized aphids on the test varieties were crushed with a forceps, and the contaminated culture pots were destroyed.

RESULTS

One hundred and forty-five of the 1295 test barley varieties rated 3 or less on damage rating and were considered to be resistant. These were subjected to two further retests (Table I).

After the elimination of 15 varieties through the subsequent two retests, 130 varieties were selected as resistant to the greenhouse strain. Tests were also conducted with these 145 varieties for reaction to the field strain greenbug in the Small Grains greenhouse. It was considered possible to find differences in reaction to the two strains of the greenbug but barley varieties that were resistant to the greenhouse strain were also resistant to the field strain and no noticeable difference was discovered.

The susceptible check (C_1) Sel. 28-A wheat and test varieties were totally killed after the second week of infestation (Figure 2), and the aphids migrated to other living plants which, along with the resistant check (C_2) Omugi barley, began to show signs of recovery from injury. Omugi barley and other highly tolerant barley varieties were also less preferred than Sel. 28-A. A random count of the total number of greenbugs on 25 rows of resistant and susceptible check lines was made.

The 25 resistant check lines had an average number of 80.8 greenbugs per plant and an injury rating of 1.5. The susceptible check lines had an average of 134.3 greenbugs per plant and an average injury rating of 3.0 after one week of infestation. A second count of the aphid population was not taken since the population declined with increasing damage to the susceptible checks. The lower population of aphids on the 25 resistant lines showed the factor of antibiosis was involved in their resistance.

Of the 55 commercially adapted varieties 9 proved to be resistant to the two greenbug strains (Table 2).

DISCUSSION AND CONCLUSIONS

Screening of 1295 winter barley varieties from the World Collection and 55 commercially accepted barley varieties was undertaken to find resistance against the greenhouse strain of the greenbug. Of the World Collection 130 were found to have a resistance comparable to or better than Omugi, and of the commercial varieties 9 showed as much resistance as Omugi.

In the tolerance test of the 130 World Collection barleys, 44 varieties were rated better than Omugi and of these 3 were rated 1.3 and 41 were rated 1.6 when Omugi was rated 2. Seventy-seven varieties received a rating of 2, 6 others rated 2.6, and 3 were rated to have a low resistance of 3.

Chada (9) reported 14 barley varieties from 1230 varieties tested to have resistance to the field strain of the greenbug. Thirteen of these were included in our tests, 2 rated 1.3, 6 rated 1.6 and 5 rated 2, or had resistance comparable to that of the Omugi check.

Hormchong (22) investigated the resistance of barley to the corn leaf aphid. One of the selections he reported as highly resistant to the corn leaf aphid, was rated 2 for resistance to the greenhouse strain. Two varieties moderately resistant to the corn leaf aphid, were rated 2 in the present test. Thus, 3 selections having resistance towards these 3 types of aphids are available for future breeding work.

One of the aims of this study was to discover whether or not resistance in barleys to the greenhouse strain is governed by genes other than those responsible for resistance to the field strain. The results failed to indicate such difference, since the varieties showed similar reaction to the two strains. Therefore, it can be assumed that no new genes for resistance to the greenhouse strain have developed. Genes which constitute resistance, generally develop as a result of active protection reactions of the host tissue against the attack of an insect pest.

In this instance the greenhouse strain seems adapted to the particular genetic make-up of Dickinson Sel. 28-A which is resistant to the field strain, on which it successfully feeds.

The assumption that the inability of aphids to remove auxins from tolerant varieties could result from failure to penetrate certain vascular or phloem feeding areas, should be re-examined by the study of the differences in the mechanics of the feeding of the two strains of the greenbug.

Maxwell and Painter (29) have reported the tolerance component of resistance to be closely associated with the free-auxin content of plants and the ability of certain aphids to extract and concentrate these growth substances. Investigation should be made of the variations of the auxin contents of extracts of greenbug strains feeding on both tolerant and susceptible hosts. Such data may provide a better understanding of the relationship of greenbug tolerance to auxin contents.

Investigation of differences in nutritional requirements (31) of the two biotypes is likely to yield useful data.

SUMMARY

Experiments were conducted in a search of new sources of resistance against a greenbug biotype (Greenhouse strain) and to discover differential resistance to the two greenbug strains. This could be utilized in future breeding work to augment the resistance of the present varieties that are resistant to the normal field strain.

A total of 1295 winter barley varieties and selections with 55 commercially accepted varieties were screened in the greenhouse for resistance to the greenhouse strain of the greenbug.

From 130 selected varieties 44 possessed a high degree of resistance, greater than that of resistant Omugi barley; 77 varieties were equal to Omugi and 9 varieties had moderate to low resistance. Nine commercially accepted varieties possessed high resistance to both greenbug strains.

The varieties that were resistant to the field strain of the greenbug were also resistant to the greenhouse strain. Three varieties having high resistance to both greenbug strains possessed high to moderate resistance against the corn leaf aphid.

Tests indicated the mechanism of resistance involved tolerance and antibiosis.

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A P P E N D I X

Table 1. Resistance of 130 winter barley varieties and selections to a greenbug biotype.

Entry Number	Variety	C. I. or Selection Number	Test No. 1 Injury Rating at Days after infestation 7	14	21	Test No. 2 7	14	21	Test No. 3 7	14	21	Mean Rating
603	Unnamed	7529	1	2	2	1	1	1	1	1	1	1.3
604	do.	7530	1	2	2	1	1	1	1	1	1	1.3
781	Hosokawanishiki	8934	1	2	2	1	1	1	1	1	1	1.3
346	Tongpori	5208	1	1	2	1	1	1	1	2	2	1.6
350	Raishu	5214	1	1	2	1	1	1	1	2	2	1.6
357	Seibaku	5229	1	1	2	1	1	1	1	2	2	1.6
358	Obaku	5231	1	1	2	1	1	1	1	2	2	1.6
360	Shokum	5233	1	1	2	1	2	2	1	1	1	1.6
374	Koranbaku	5253	1	2	2	0	1	1	1	2	2	1.6
471	Unnamed	7098	1	2	2	0	1	1	1	2	2	1.6
483	do.	7294	1	2	2	0	1	1	1	2	2	1.6
527	Chae-rae-bac	7405	1	2	2	0	1	1	1	2	2	1.6
529	Chae-rae chang	7407	0	1	2	1	1	1	1	2	2	1.6
531	Chang-mang-ryuac-kac	7409	1	2	2	0	1	1	1	2	2	1.6
536	Chung-mae 15	7414	1	2	2	0	1	1	1	2	2	1.6
539	Kyo-bae 35	7418	1	2	2	0	1	1	1	2	2	1.6
540	Kyong-nam 89	7419	1	2	2	0	1	1	1	2	2	1.6
541	Mammoat	7420	1	2	2	0	1	1	1	2	2	1.6
553	Suwon 5	7432	1	2	2	0	1	1	1	2	2	1.6
558	Suwon 8	7437	1	2	2	0	1	1	1	2	2	1.6
560	Suwon 13	7439	1	2	2	1	1	1	1	2	2	1.6
564	Suwon 15	7443	1	2	2	1	1	1	1	2	2	1.6
569	Suwon 26	7448	1	2	2	1	1	1	1	2	2	1.6
847	Suwon No. 4	9230	1	2	2	1	1	1	1	2	2	1.6
849	Suwon No. 6	9232	1	2	2	1	1	1	1	2	2	1.6
853	Suwon No. 13	9238	1	2	2	1	1	1	1	2	2	1.6
884	P'un K'un 1,28	9321	1	2	2	1	1	1	1	2	2	1.6
904	Chin Niu Chen	9344	1	2	2	1	1	1	1	2	2	1.6
905	Hain an Tien 1	9345	1	2	2	1	1	1	1	2	2	1.6
906	do. 2	9346	1	2	2	1	1	1	1	2	2	1.6
909	Chiao Chuang 3	9349	1	2	2	1	1	1	1	2	2	1.6

Table 1. Continued.

Entry Number	Variety	C. I. or Selection Number	Test No. 1 Injury Rating at Days after infestation 7	14	21	Test No. 2 7	14	21	Test No. 3 7	14	21	Mean Rating
915	Tching Chou 8	9355	1	2	2	1	1	1	1	2	2	1.6
929	Kadaka-rokkaku 78	9377	1	2	2	1	1	1	1	2	2	1.6
936	Shiro-yoshigara 22,96	9384	1	2	2	1	1	1	1	2	2	1.6
968	Oshin, 688	9457	1	2	2	1	1	1	1	2	2	1.6
1143	Unnamed	10137	1	2	2	1	1	1	1	2	2	1.6
1146	do.	10171	1	2	2	1	1	1	1	2	2	1.6
1147	do.	10174	1	2	2	1	1	1	1	2	2	1.6
1175	do.	10263	1	2	2	1	1	1	1	2	2	1.6
1176	do.	10264	1	2	2	1	1	1	1	2	2	1.6
1184	do.	10293	1	2	2	1	1	1	1	2	2	1.6
1186	do.	10295	1	2	2	1	1	1	1	2	2	1.6
1208	do.	10345	1	2	2	1	1	1	1	2	2	1.6
1261	do.	10717	1	2	2	1	1	1	1	2	2	1.6
301	Unnamed	5043	1	2	2	1	2	2	1	2	2	2
309	do.	5093	1	2	2	1	2	2	1	2	2	2
310	do.	5096	1	2	2	1	2	2	1	2	2	2
311	Koso	5134	1	2	2	1	2	2	1	2	2	2
313	Kido	5145	1	2	2	1	2	2	1	2	2	2
320	Zairai	5153	1	2	2	1	2	2	1	2	2	2
321	Dorshu	5154	1	2	2	1	2	2	1	2	2	2
325	Tongu	5159	1	2	2	1	2	2	1	2	2	2
331	Nando	5168	1	2	2	1	2	2	1	2	2	2
332	Changu	5169	1	2	2	1	2	2	1	2	2	2
338	Hoku	5179	1	2	2	1	2	2	1	2	2	2
362	Dobaku	5238	1	2	2	1	2	2	1	2	2	2
369	Tori	5246	1	2	2	1	2	2	1	2	2	2
371	Gubori	5248	1	2	2	1	2	2	1	2	2	2
372	Shonuru	5251	1	2	2	1	2	2	1	2	2	2
373	Tongubori	5252	1	2	2	1	2	2	1	2	2	2

Table 1. Continued

Entry Number	Variety	C. I. or Selection Number	Test No. 1			Test No. 2			Test No. 3			Mean Rating
			Injury Rating at Days after infestation									
			7	14	21	7	14	21	7	14	21	
375	Nandomugi	5254	1	2	2	1	2	2	1	2	2	2
378	Dicktoo	5529	1	2	2	1	2	2	1	2	2	2
436	Unnamed	6590	1	2	2	1	2	2	1	2	2	2
439	do.	6672	1	2	2	1	2	2	1	2	2	2
469	do.	7081	1	2	2	1	2	2	1	2	2	2
486	do.	7297	1	2	2	1	2	2	1	2	2	2
509	Aizu	7364	1	2	2	1	2	2	1	2	2	2
528	Chae-rae-bac	7406	1	2	2	1	2	2	1	2	2	2
530	do.	7408	1	2	2	1	2	2	1	2	2	2
549	Suwon 3	7428	1	2	2	1	2	2	1	2	2	2
554	Suwon 5	7433	1	2	2	0	1	2	1	2	2	2
557	Suwon 7	7436	1	2	2	1	2	2	1	2	2	2
561	Suwon 13	7440	1	2	2	1	2	2	1	2	2	2
572	Suwon 29	7451	1	2	2	1	2	2	1	2	2	2
573	Suwon 31	7453	1	2	2	1	2	2	1	2	2	2
574	do.	7454	1	2	2	1	2	2	1	2	2	2
577	Yong-wol-ryuc-kac	7457	1	2	2	1	2	2	1	2	2	2
600	Ludwig	7525	1	2	2	1	2	2	1	2	2	2
775	Aizu No. 4	8925	1	2	2	1	2	2	1	2	2	2
776	Aizu	8926	1	2	2	1	2	2	1	2	2	2
833	Unnamed	9215	1	2	2	1	2	2	1	2	2	2
838	Hoe-raang-chae-rae	9221	1	2	2	1	2	2	1	2	2	2
840	Kwan Chi	9223	1	2	2	1	2	2	1	2	2	2
841	Kyong No. 1	9224	1	2	2	1	2	2	1	2	2	2
842	Kyong No. 2	9225	1	2	2	1	2	2	1	2	2	2
843	Kyong No. 3	9226	1	2	2	1	2	2	1	2	2	2
846	Suwon No. 3	9229	1	2	2	1	2	2	1	2	2	2
850	Suwon No. 7	9233	1	2	2	1	2	2	1	2	2	2
873	Kamairazu	9284	1	2	2	1	2	2	1	2	2	2

Table 1. Continued

Entry Number	Variety	C. I. or Selection Number	Test No. 1 Injury Rating at Days after infestation			Test No. 2			Test No. 3			Mean Rating
			7	14	21	7	14	21	7	14	21	
878	Chan Tung 22	9315	1	2	2	1	2	2	1	2	2	2
879	Li Ta Un 1,23	9316	1	2	2	1	2	2	1	2	2	2
880	Li Ta'Un 2,24	9317	1	2	2	1	2	2	1	2	2	2
881	Unnamed	9318	1	2	2	1	2	2	1	2	2	2
882	Chiao Hsien 26	9319	1	2	2	1	2	2	1	2	2	2
907	Hain an Tien 3	9347	1	2	2	1	2	2	1	2	2	2
913	Tching Chou 3	9353	1	2	2	1	2	2	1	2	2	2
914	do.	9354	1	2	2	1	2	2	1	2	2	2
963	Muraki-Omugi (Haihoku) 759	9446	1	2	2	1	2	2	1	2	2	2
964	Neistsu-rokkaku, 739	9450	1	2	2	1	2	2	1	2	2	2
966	Zairai-shiro, 705	9454	1	2	2	1	2	2	1	2	2	2
972	Hoon, 629	9462	1	2	2	1	2	2	1	2	2	2
982	Geijitsu mantonpori	9473	1	2	2	1	2	2	1	2	2	2
1010	Mo. B 893	9516	1	2	2	1	2	2	1	2	2	2
1069	Unnamed	9897	1	2	2	1	2	2	1	2	2	2
1080	do.	9941	1	2	2	1	2	2	1	2	2	2
1113	Aizu No. 2	10059	1	2	2	1	2	2	1	2	2	2
1142	Unnamed	10126	1	2	2	1	2	2	1	2	2	2
1231	Unnamed	10673	1	2	2	1	2	2	1	2	2	2
1236	do.	10681	1	2	2	1	2	2	1	2	2	2
1239	do.	10685	1	2	2	1	2	2	1	2	2	2
1246	do.	10692	1	2	2	1	2	2	1	2	2	2
1252	do.	10706	1	2	2	1	2	2	1	2	2	2
1254	do.	10708	1	2	2	1	2	2	1	2	2	2
1262	do.	10718	1	2	2	1	2	2	1	2	2	2
1263	do.	10719	1	2	2	1	2	2	1	2	2	2
1267	do.	10726	1	2	2	1	2	2	1	2	2	2

Table 1. Continued

Entry Number	Variety	C. I. or Selection Number	Test No. 1 Injury Rating at Days after infestation 7	14	21	Test No. 2 7	14	21	Test No. 3 7	14	21	Mean Rating
1269	do.	10742	1	2	2	1	2	2	1	2	2	2
1273	Unnamed	10746	1	1	2	1	2	2	1	2	2	2
1274	do.	10747	1	2	2	1	2	2	1	2	2	2
1275	do.	10748	1	2	2	1	2	2	1	2	2	2
1276	do.	10750	1	2	2	1	2	2	1	2	2	2
979	Koyosaira, 509	9470	1	2	2	1	2	3	1	2	2	2.3
1264	Unnamed	10720	1	2	2	1	2	2	1	2	3	2.3
210	Unnamed	4171	1	2	2	2	2	3	1	2	3	2.6
211	do.	4172	1	2	2	2	2	3	1	2	3	2.6
446	Wong	6728	1	2	2	1	2	3	1	2	3	2.6
1270	Unnamed	10743	1	2	2	1	2	3	1	2	3	2.6
381	do.	5558	2	2	3	1	2	3	2	3	3	3
382	do.	5559	1	2	3	1	2	3	2	3	3	3
441	do.	6683	1	2	3	1	2	3	2	3	3	3
	Dickinson Sel. 28-A		2	3	5	2	3	5	2	3	5	5
	Wheat susceptible check	(C_1)										
	Omugi barley		1	2	2	1	2	2	1	2	2	2
	Resistant Check	(C_2)										

Table 2. Resistance of commercial varieties and selections to the two greenbug strains.

Entry Number	Name	C.I. Number	State or Selection Number	Injury Rating: Greenhouse Strain	Injury Rating: Field Strain
1	Rogers x Omugi	11664	Stw 58267	2	2
4	Rogers x Kearney		Stw 605592	2	2
7	Chase	9581		2	2
8	Meimi	5136		2	2
9	Kyong # 2	9225		2	2
10	Omugi	5144		2	2
16	Kearney	7580		2	2
30	Mo. B 1371	11356		2	2
47	Will (C.I. 10880 Sel.)		Stw 633140	2	2
	Dickinson Sel. 28-A (Check)			5	2

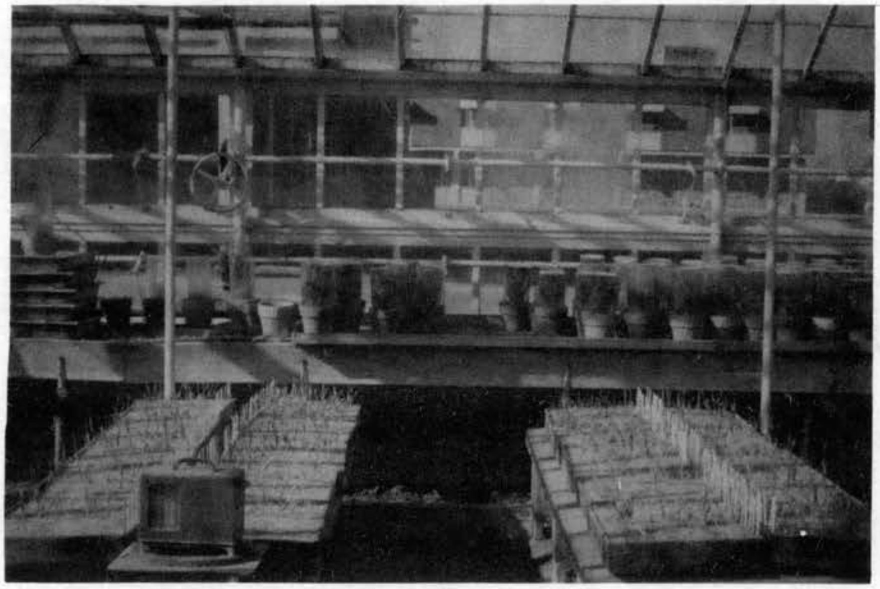

Figure 1. General lay-out of a screening test in the greenhouse.

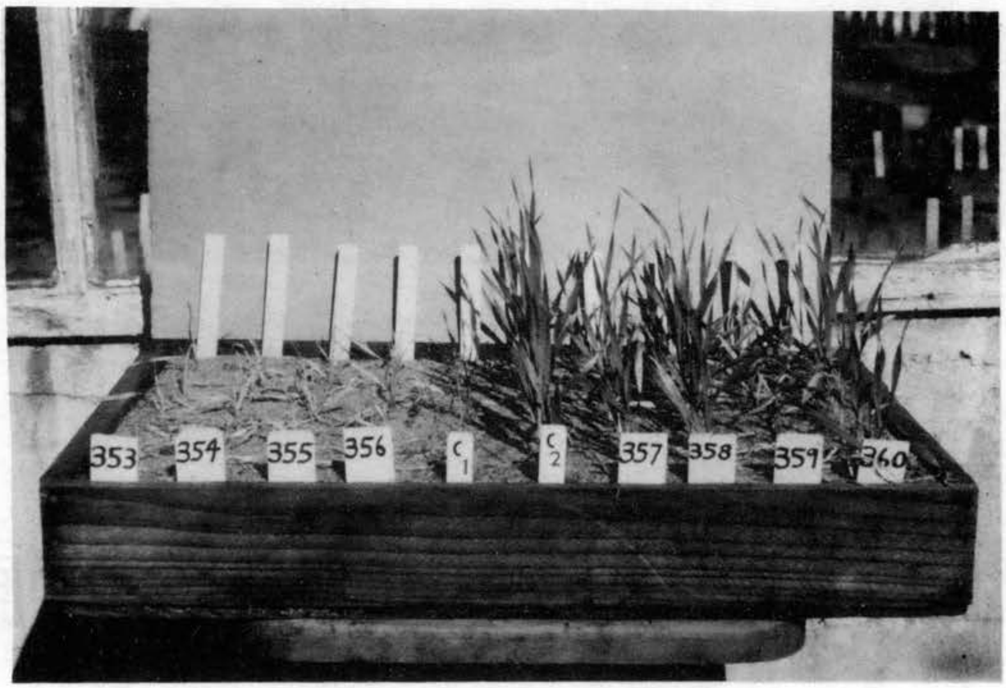

Figure 2. A test flat showing the susceptibility and tolerance of barley varieties as compared to the susceptible check (C_1) Sel. 28-A wheat and resistant check (C_2) Omugi barley.

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