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EVALUATION OF WHEAT, BARLEY AND SORGHUM GERMPLASM FOR RESISTANCE TO THE GREENBUG, *SCHIZAPHIS GRAMINUM* (RONDANI)

C. Inayatullah, PhD
Principal Investigator

Nahid Mahmood, MPhil
Senior Scientific Officer

National Agricultural Research Centre
Pakistan Agricultural Research Council
Islamabad

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1.0 SUMMARY

The studies were initiated in August, 1989. A preliminary survey was conducted in the Punjab and North Western Frontier Province (NWFP). Heavy infestations of greenbug, *Schizaphis graminum* (Rondani), infestations were recorded at Charsadda, Sher Shah (Multan) and Malkot (Murree). However, it was found in small numbers at Mingora, Rawalpindi, Burhan, Faisalabad, Multan, Khanewal, Chani Kot (Rahim Yar Khan), Lodhran, and Bargah Sharif (Bahwalpur).

Culture of the greenbug collected from Charsadda was established on wheat cultivar 'Faisalabad-83'. At first a seedling bulk test was conducted with the local and exotic host cultivars to determine the biotypic status of the greenbug found in Charsadda so as to compare the results with the biotypes found in the USA. In the USA 6 biotypes (designated A through F) are found. During the present studies 'DS-28A' and 'Largo' wheat were found susceptible to this population, whereas 'Amigo' wheat, 'Post' and 'Will' barley were found to be resistant. Thus the present population of greenbug seemed to be nearest to biotype B found in the USA, but entirely different. It is designated as biotype PK-1 for future reference.

Of the 44 recommended wheat cultivars, 'Punjab-85' was found to be resistant with a damage rating of 3 at 0 to 9 damage scale (0, healthy; 9, dead). 'Faisalabad-85' was moderately resistant

with a damage rating of 4, 'PARI-73', 'Sandal' and 'Yecora' had a damage rating of 5, and 'PAK-81', 'WL-711', 'Sutluj-86' and 'Nuri-70' had a damage rating of 6. All the remaining cultivars were highly susceptible to greenbug (damage rating > 6).

Three tests, antixenosis, antibiosis and tolerance were conducted to determine the nature of resistance in selected entries, especially 'Punjab-85' In antixenosis (non-preference) test, 'PARI-73', 'WL-711' and 'Yecora' were found to be the least preferred (mean number of greenbugs 1-2/plant). The lowest fecundity (antibiosis) of the greenbug was on 'Punjab-85'. In the tolerance test, the lowest damage was recorded on 'PARI-73' (damage rating 4.10), followed by 'Sandal' (4.80) and 'Punjab-85' (4.8). These three tests indicated that resistance in 'Punjab-85' is mainly due to antibiosis and low level of tolerance.

During this study 439 wheat germplasm lines were tested. Of these 16 germplasm lines ('PAK 15081', 'PAK 15115', 'PAK 15139', 'PAK 15242', 'PAK 15433', 'PAK 15479', 'PAK 15481', 'PAK 15519', 'PAK 15992', 'PAK 15994', 'PAK 15995', 'PAK 15997', 'PAK 16007', 'PAK 16008', 'PAK 16010' and 'PAK 16190') were found to have high level of resistance. Of the test entries, 114 were moderately resistant and the remainder were susceptible to greenbug.

Eighty-one barley entries were tested. Of these 8 ('PAK 30095', 'PAK 30101', 'PAK 30104', 'PAK 30128', 'PAK 30133', 'BA-1 2', 'BYT (MRA) 9', and 'BYT (MRA) 11') had high level of resistance. Twenty-one lines were moderately resistant and the remainder were highly susceptible to greenbug.

Tests conducted with 184 sorghum germplasm lines indicated that 5 lines ('PAK 80043', 'PAK 80044', 'PAK 80255', 'PAK 80303' and 'PAK 80305') were highly resistant, 41 lines were moderately resistant and the remainder were susceptible to greenbug.

Test conducted with 36 pearl millet germplasm lines indicated that 3 lines ('PAK 75060', 'PAK 75076' and 'PAK 75081') were highly resistant and 20 were moderately resistant, whereas the remainder lines were susceptible to greenbug.

The recommended wheat cultivars were also tested against bird cherry-oat aphid. 'Faisalabad-85', 'PARI-73', 'Rawal-87' and 'Punjab-81' were found to be highly resistant. The cultivars, 'WL-711', 'Yecora', 'Kohinoor-83', 'Sandal', 'Pirsabak-85', 'Tandojam-83', 'PAK-81', 'Pavon', 'Mexipak', 'SA-75', 'ARZ', 'BWP-87' and 'Lyallpur-73' were moderately resistant, whereas the remainder cultivars were susceptible.

Since the greenbug resistance, especially in wheat, is monogenic, the germplasm found resistant may have genes different from those already found, and can be exploited in breeding programs.

2.0 INTRODUCTION

A number of aphid species (Homoptera: Aphididae) attack on cereals in the world. These cause damage by (i) extraction of plant sap, (ii) injection of toxic secretions while feeding, and (iii) transmission of viral diseases. Of these, grain aphid, *Sitobion avenae* (Fabricius), *Sitobion miscanthi* (Takahashi), bird cherry-oat aphid, *Rhopalosiphum padi* (L.), corn leaf aphid, *Rhopalosiphum maidis* (Fitch), rose-grain aphid, *Metopolophium dirhodum* (Walker), and greenbug, *Schizaphis graminum* (Rondani) are the serious pests of cereals around the world (Carter et al. 1982; Starks et. al. 1983; Dixon, 1987). These species are also vectors of barley yellow dwarf mosaic (BYDM) virus which is a global problem (Plumb, 1983; Ullman, 1988; Fereres et al. 1989). Recently, Russian wheat aphid, *Diuraphis noxia* (Mordvilko) has appeared as a serious pest of cereals in the USA (Araya et al. 1987; Webster & Starks, 1987).

In South-East Asia, Lefroy (1909) was the first to report grain aphid on wheat. Das (1918) has mentioned corn leaf aphid, *Melanaphis sacchari* (Zehntner), grain aphid and greenbug from wheat (*Triticum aestivum* L.), barely (*Hordeum vulgare* L.), oats (*Avena sativa* L.) and sorghum (*Sorghum bicolor* L. Moench). Ullah (1940) reported corn leaf aphid, grain aphid and greenbug on sorghum and wheat from Delhi. Recently, Hamid (1983) surveyed Pakistan and reported *Forda formicaria* von Heyden and *Melanaphis*

sacchari attacking on sorghum; *Myzus obtusirostris* David, Narayanan and Rajasingh attacking on corn (*Zea mays* L.); corn leaf aphid attacking on wheat and sorghum; bird cherry-oat aphid attacking on wheat and corn; greenbug attacking on wheat, barely and sorghum; *Sipha maydis* Passerini attacking on wheat, barley, sorghum and corn; and grain aphid attacking on wheat and barley. Recently a survey has been conducted in Pakistan and at least 45 species of aphids attacking on shoots and roots of grasses have been recorded (K. Etienne-Neumann, Pers. Commun., 1990).

The greenbug is a cosmopolitan pest of many graminaceous crops. It has been recorded from 46 countries. It has been a major pest of small grains and sorghum in the USA (Starks and Burton, 1977), Canada (Twinn, 1932), Urguay (Silveira and Conde, 1945), Argentina (Griot, 1944), Hungary, Italy (Wadley, 1931), Bulgaria (Kontev, 1976), Yugoslavia (Mitic-Muzina and Srdic, 1977), Romania (Barbulescu, 1976), Egypt (Ali and Rizk, 1979), Sudan (Muddathir, 1976), Iraq (Ali et al. 1985), Kenya (Walker, 1954), South Africa (Brown, 1971), Botswana (Flattery, 1982), Pakistan (Hamid, 1983), India (Chaudhry et al., 1969), China (Li, 1986; Feng & Yang, 1987) and in the USSR (Kushnerik, 1981). Potter (1982) reported that besides small grains and sorghum, greenbug is a major pest of Kentucky bluegrass, *Poa pratensis* L., in the USA. Myrzin and Shilovskii (1983) and Kazanok (1986) reported that it is major pest of rice in the USSR. In Australia, it is a major pest of Pangola grass, *Digitaria decumbens* (Franzmann, 1973), and in Sweden of meadow grasses, *Phleum pratense* L. (Ossiannilsson, 1948). References pertaining

to greenbug can be found in the bibliography published by Walker et al. (1972).

According to Pettersson (1971) greenbug attacks on about 96 various graminaceous host plants. Recently Michels (1986) has published a list of 70 plant species in 44 genera as hosts of greenbug in North America. In addition to BYDM, greenbug is also a vector of maize dwarf mosaic (Nault et al. 1971), sugarcane mosaic (Komblas and Long, 1972), and abaca mosaic (Gavarra and Eloja, 1969) viruses.

George (1974, 1975) and Kolbe (1970) have shown that cereal aphids can cause considerable yield losses in some years. The damage, however, varies from year to year (Carter et al. 1980; Rabbinge et al. 1979) and from place to place (George and Gair, 1979). Burton (1986) demonstrated that due to greenbug attack both root and shoot biomass is decreased. In two weeks attack time, the difference is 4-fold. Greenbug damage occurs both in autumn as well as in spring. Burton et al. (1985) reported that autumn damage to the susceptible variety hard red winter wheat 'TAM W-101' and a resistant one ('TAM W-101/Amigo'), was generally more sever than spring damage. Plants damaged in autumn appeared to recover, but ultimately exhibited a marked decrease in grain yield at spring harvest. The economic thresholds in autumn were <10 aphids/plant, while in spring they were < 20/plant for the susceptible variety. Kieckhefer and Kantack (1986, 1988) calculated the yield losses in barley and wheat in caged plots with artificial infestations of cereal aphids. Greatest losses in yield were caused by aphids feeding

during the seedling (2-3 leaf) stage; mean densities of 25-30 aphids per stem resulted losses of about 50% in some yield components at this stage. Further they reported that greenbug and bird cherry-oat aphid were more damaging than grain aphid or corn leaf aphid.

Since the first infestation of greenbug in the USA in Virginia in 1882, at least 19 outbreaks have occurred. A serious one hit Texas and Oklahoma in 1942. As a result more than 1.66 million metric tons of grains valued at $38 million were lost. Other serious outbreaks in Oklahoma occurred during 1901, 1903, 1906, 1907, 1916, 1922, 1933, 1934, 1939, 1949-51, 1961, 1968 and 1976 (Rogers et al. 1972; Starks and Burton, 1977). In 1976, damage and control costs on wheat in Oklahoma alone exceeded $80 million (Starks and Burton, 1977).

In Pakistan Hamid (1983) reported locally damaging populations of greenbug in Western hills, Northern hills and Peshawar valley; and those of grain aphid in Western hills, Northern hills, Peshawar valley, and foothills of Punjab. During 1987 severe infestations of grain aphid were reported in Bahwalpur and Multan area. No other information is available on the losses caused by cereal aphids in Pakistan.

In Great Britain cereal aphids were not considered as important pests until 1968, when they reached very high levels on wheat (Fletcher and Bardner, 1969). Carter et al. (1982) reported that over the last decade considerable changes have occurred in the cultivation of wheat in Western Europe. High

sowing densities, split nitrogen dressing and top dressing at flowering have resulted in crops that remain suitable for cereal aphids up to the end of crop growth. In Pakistan also the cereal aphids were not considered as pests until about 2 decades ago. In Pakistan low-yielding native varieties of wheat are being replaced with high-yielding varieties developed from crosses with 'Mexican' strains, while new hybrids of sorghum and corn have been introduced from USA. Most of the 'Mexican' cultivars are susceptible to greenbug. These new varieties with different genetic make-up present new situations for greenbug and other aphids, and therefore, can create new problems. The use of resistant varieties is an effective and efficient tool for the control of cereal aphids (Starks et al. 1983). Thus the present studies were initiated to evaluate the local wheat, barley, sorghum and millets cultivars and germplasm for resistance against greenbug. Since there are not many genes for resistance against greenbug, especially in wheat, discovery of a new gene(s) which confer(s) resistance will have an immense value.

3.0 REVIEW OF LITERATURE

The use of resistant varieties is an effective control measure against the cereal aphids. Since the recognition of greenbug as a damaging pest, resistant varieties of both small grains and sorghum have been released (Starks et al. 1983; Webster and Inayatullah, 1984; Webster et al. 1986; Tyler et al. 1987a,b). However, for reasons that favor greenbug evolution (parthenogenesis, paedogenesis, and short life cycle), biotypes that overcome varietal resistance have developed and hindered the development of new resistant varieties (Porter et al. 1982; Starks et al. 1983). A biotype is defined as "a group of individuals of the same species which may or may not differ morphologically but differ in biological functions such as different susceptibilities to insecticides, different virus-transmitting abilities, different levels of resistance to pathogens, different feeding behaviors, and different host preferences (Eastop, 1973). References pertaining to biotypes in aphids may be found in Webster and Inayatullah (1985). Six biotypes (designated A through F) and several isolates of the greenbug have been detected in the USA (Kindler and Spomer, 1986). All these biotypes are designated on the basis of their ability to kill various cultivars of cereals, except biotype D which has the host reaction similar to biotype C but is resistant to organophosphate insecticides (Peters et al. 1975; Puterka and Peters, 1988).

Biotype A of the greenbug predominated in the Great Plains of USA until the early 1960's. Biotype B appeared in 1958 (Wood, 1961) and became abundant to biotype A by 1965. Biotype C was detected in 1968, and it has caused extensive damage to grain sorghum (Harvey and Hackerott, 1969). Later it became the predominant biotype in the Great Plains of the USA. Before the occurrence of biotype C, greenbug used to damage only winter hosts, like, wheat, barley, oats, etc. Its survival during summer was very poor because of high temperatures. However, biotype C is adapted to survive under high temperature.

With the occurrence of biotype C, control strategy was changed a little, and extensive insecticides were used against it. However, biotype D, having the same host plant reaction as biotype C, but having a high level of resistance to organophosphate insecticides appeared in the higher insecticide usage locations in the Edmonson, Texas, area in 1974 (Teetes et al. 1975; Peters et al. 1975; Chang et al. 1980).

A new biotype designated as E, appeared in Bushland, Texas, in 1980. This biotype had a potential to overcome resistance in some of the wheat, barley, oats and sorghum lines resistant to biotype C (Starks et al. 1983). Moreover, biotype E has been reported to be a more efficient vector of some isolates of maize dwarf mosaic virus than biotype C (Berger et al. 1983).

Biotype F is nearest to biotype A in terms of plant response, but it differs in its ability to kill 'Amigo' wheat,

and in morphology, having no dorsal stripe. Biotype F is also capable of killing 'Reubens' Canada bluegrass, *Poa compressa* L., which is highly resistant to the other greenbug biotypes (Kindler and Spomer, 1986).

Considerable work has been conducted to determine the mechanisms of resistance against greenbug. Its feeding mechanisms differ from host to host plant. In barley the feeding path of biotype A is intercellular, ending in phloem, whereas that of biotype B is intracellular and intercellular, ending in the mesophyll parenchyma. Biotype C feeds in the vascular bundles of sorghum leaves (Wood, 1971) and the phloem of sorghum (Campbell et al. 1982). Al-Mousawi et al. (1983) based on their ultrastructural studies of greenbug feeding damage to susceptible and resistant wheat cultivars concluded that the resistance in wheat is physiological and biochemical.

El-Serwiy et al. (1985) have reported that barley strains with thinner layers of sclerenchyma cells and larger numbers of vascular bundles are highly preferred by greenbug. Tsumuki et al. (1987) reported that the degree of resistance in barley is positively correlated with surface wax, whereas susceptibility increased with increasing contents of sugars and free amino acids in the leaves. Starks and Weibel (1981) have demonstrated that bloomless and sparse-bloom sorghum have high level of antixenosis against greenbug biotype C. Campbell and Dreyer (1985) have investigated the relationship between plant matrix polysaccharides to host-plant-biotype compatibility. They concluded that the biotypes are able to hydrolyze the sorghum

pectic substances of susceptible sorghum variety at a greater rate than those of a resistant sorghum variety. Kanehisa et al. (1987) mentioned that over 40 compounds decrease aphid survival, and among these gramine, benzoxazolinone and phenolic acids are the most effective. Zuniga and Corcuera (1986) have reported that the incorporation of gramine in artificial diet of bird cherry-oat aphid resulted in the decreased survival, amount of diet ingested and the number of nymphs produced. Thus the gramine contents in the plant effect the feeding behavior of aphids (Zuniga et al. 1988).

The greenbug biotypes not only differ in their ability to kill the host plants, but also differ in many other traits. Fargo et al. (1986), Inayatullah et al. (1987a) and Inayatullah et al. (1987b) have reported the morphometric variation within various morphs and biotypes of the greenbug biotypes. They concluded that these biotypes are distinct groups of population. Peters et al. (1988) compared the biological fitness of biotypes B, C, and E. Biotype B was less successful in feeding from the phloem of susceptible 'Wintermalt' but was relatively more successful than biotypes C and E on the resistant 'Post'. Development, reproduction and particularly dry weight of biotype B were inferior to those of biotypes C and E on both resistant and susceptible plants. However, biotype B caused the greatest overall reduction in chlorophyll content of infested leaves and was considered the most damaging but least biologically fit of the 3 biotypes. Niassy et al. (1987) have reported variation in feeding behavior, fecundity and damage of biotypes B and E. Ryan

et al. (1987) have reported the feeding behavior, fecundity and honey dew reproduction of biotypes C and E on resistant and susceptible wheat.

The development of biotypes in greenbug indicate high variability in this species. These biotypes may become reproductively isolated and result into new species (Inayatullah et al. 1987a). Recently Eisenbach and Mittler (1987) have reported the ability of male aphids of 2 different biotypes (C & E) of greenbug to distinguish ovipara-produced sex pheromone of their own biotype from that of the other biotype. Biotype E males showed a strong preference for biotype E oviparae; the preference of biotype C males for biotype C oviparae was less marked. The behavioral findings indicate a potential biochemical reproductive isolating mechanism for these biotypes.

4.0 MATERIALS AND METHODS

4.1 Establishment of Culture

The greenbugs were collected from Charsadda (North Western Frontier Province) attacking on wheat in November, 1988. About 20 seeds of wheat cultivar 'Faisalabad-83' were sown in a plastic pot (11.5 cm diameter, 11 cm high). The pots were kept in a rearing cage measuring 112 x 50 x 62 cm. Left, right and rear sides of the cage were covered with muslin cloth to facilitate aeration. On the front side, two doors were provided and transparent plastic was used to facilitate visibility. To provide adequate light to the plants, 5 fluorescent tubes (20 W) were provided at the top of the cage. In each cage 2 incandescent bulbs (45 W) were provided to provide yellow light. The temperature in the rearing room was maintained at 27 $\pm$ 3 ^{o}C, and the relative humidity was 60%. The photoperiod was 16:8 hr day:night.

When the seedlings were about 15 cm high, these were infested with the greenbugs. The plants were fertilized with phostrogen (Phostrogen Ltd., UK). The greenbugs were allowed to develop. After an interval of 3 days, the pots with dead plants were replaced with new healthy plants. The greenbugs automatically shifted on healthy plants.

4.2 Procurement of Test Material

Plant Genetic Resources Program, National Agricultural Research Centre (NARC), Islamabad, has established a bank of germplasm of various crops. In this bank all the local varieties/germplasm are deposited. In addition, some varieties/Germplasm from neighboring countries have also been procured. Seeds of wheat, barley, sorghum and pearl millet (*Pennisetum americanum* (L.)) were obtained from this section. Seeds of some of the recommended wheat cultivars were also obtained from the National Coordinated Wheat, Barley and Triticale Program, NARC.

Seeds of some of the host differentials used to differentiate the greenbug biotypes were obtained from USDA-ARS, Plant Science Research Facility, Stillwater, Oklahoma, USA.

4.3. Seedling Bulk Test

One row of each test entry was sown in a metal tray measuring 51 x 35 x 9 cm. There were about 20 seedlings in a row, and 9 rows in a tray. When the seedlings were about 5 cm high, greenbugs were released on them at the rate of about 10 greenbugs per seedling. There were 5 replications in this test. The greenbugs were allowed to develop. The plants were observed daily and if infestation level declined more greenbugs were added. After 10 days of infestation, the damage occurred to each entry was visually recorded at 0 to 9 damage scale (0, healthy; 9, dead). The entries were classified as resistant (damage

rating 0 to 3), moderately resistant (damage rating 4 to 6) or susceptible (damage rating > 6).

4.4. Antixenosis Test

The test entries were randomized and planted in a circular pattern about 3 cm from the edge of a 30 cm diameter (14 cm high) plastic pot. There was one plant of each entry in a pot. When the plants were about 5 to 8 cm tall, 50 adult greenbugs were released on the soil in the center of the pot. The plants and greenbugs were covered with a plastic cage (29 cm in diameter by 25 cm high). The tops of the cages were covered with muslin cloth. There were also two muslin cloth covered ventilation holes (5 cm diameter) in the sides of the cages. All the pots were placed in a dark room to eliminate the effect of light on the greenbug orientation towards the plants (Webster and Inayatullah, 1988). There were 10 replications and the design of the experiment was randomized complete block.

After 24 hours of the release of greenbugs, all the plants were observed and the number of greenbugs present on each plant were counted. The data were analyzed statistically, and means were separated by Duncan's New Multiple Range Test (DMRT) (Duncan, 1955).

4.5 Antibiosis Test

The seed of a selected entry was planted in a standard soil mix in 7 cm diameter (7.5 cm high) pot and thinned to one seedling per pot. Individual plants were infested at the first-leaf stage with three greenbugs from the laboratory colonies. A

small moistened brush was used to transfer the greenbugs to the test plants. Each plant was then covered with a plastic cage (6 cm diameter by 30 cm high) with a cloth top and cloth-covered ventilation holes on the sides. The cages confined the greenbugs to the proximity of the plant and also prevented contamination from occasional stray greenbugs. The plants and greenbugs were observed daily. When reproduction began, adults were removed, leaving five nymphs on each plant. Nymphs were allowed to grow on the test plant until they matured and began to reproduce. At this time, all aphids but one were removed from the plant. Nymphs were removed from the plant daily, and their numbers were recorded until the adults stopped reproducing about 20 days later. The plants were clipped periodically to facilitate handling.

The test was conducted in the laboratory at 27 $\pm$ 2° C, 60% RH and 16:8 hr regime. There were 10 replications and design of the experiment was randomized complete block. Data were analyzed statistically, and the means were separated by using DMRT.

4.6 Tolerance Test

Individual seedlings of the test entries were grown as described in the previous section. When the seedlings attained a height of 5 to 6 cm, they were infested with laboratory-reared apterous greenbug females at the rate of 10 greenbugs per seedling. The seedlings and greenbugs were covered with plastic cages described in the antibiosis section. One set of plants received no greenbugs. The plants were observed daily, and the

greenbugs were counted. The greenbugs were added or removed and a level of 10 greenbugs per plant was maintained. Twelve days later, the infested plants were visually rated for damage by using a scale ranging from 0 (no damage) to 9 (dead or dying plant). There were 10 replications and design of the experiment was randomized complete block. The data on damage ratings were analyzed statistically, and the means were separated by using DMRT.

5.0 RESULTS

5.1 Greenbug

5.1.1 Incidence of Greenbug in Pakistan

Occasional observations were made in NWFP and Punjab to estimate the density of greenbugs on wheat. At Charsadda its density was 12 greenbugs/25 plants in January, 1989. Surveys conducted in March-April, 1990, indicated that its density was 33, 12, 6, 5, 8, 4, 19, and 114 greenbugs/25 plants at Sher Shah (Multan), Pul 114 (Khanewal), Lodhran, Bargah Sharif (Bahwalpur), Chani Kot (Rahim Yar Khan), Burhan, Malkot site I and Malkot site II, respectively. It was also detected in small numbers at Mingora, Faisalabad and Rawalpindi.

5.1.2 Biotypic Status of Greenbug Population

Biotypes A and B are dark green in color with about 1/4 of the cornicle black tipped, whereas biotypes C, D and E are pale green in color, slightly elongated than A or B with cornicle green or only extremity black (Starks and Burton, 1977). According to Kindler and Spomer (1986) biotype F is similar to biotype A but without the dorsal stripe. Thus identification of biotypes is based on the reaction towards various hosts. A seedling bulk test was conducted with the host differentials obtained from USDA-ARS, Plant Science Research Facility, Stillwater, Oklahoma. The reaction of these host differentials to different biotypes of greenbug found in the USA has been

reported by Wood (1961), Starks and Burton (1977), Porter et al. (1982) Starks et al. (1983) and Kindler and Spomer (1986). The reaction towards the host differentials and some of the local checks by the US biotypes and present population of greenbug is given in Table 1. 'PI 264453' sorghum, 'Post' and 'Will' barely are resistant to all the biotypes B through E. 'Wintermalt' barley is susceptible to all the biotypes B through E. 'Amigo' wheat is resistant to biotypes B, C and D, whereas it is susceptible to biotype E. 'Largo' wheat is susceptible to biotype B but it is resistant to biotypes C, D and E (Webster et al. 1986). 'DS 28A' wheat is resistant to biotype B, whereas it is susceptible to all the other biotypes. 'Tam W-101' is susceptible to all the biotypes. Oats 'CI 1579' and 'CI 1580' are susceptible to biotype A, but resistant to biotype B through E. Oats 'CI 4888' is resistant to biotype B but susceptible to C and E (Starks et al. 1983). 'DS 28-A' wheat is highly resistant to biotype F whereas it is susceptible to biotype A. Oats 'CI 1579' and 'CI 1580' show intermediate resistance to biotype F (Kindler and Spomer, 1986). Biotype D behaves like biotype C except that it is resistant to some of the organophosphate insecticides (Peter et al. 1976).

During the present studies these host differentials showed very interesting results to the present population of greenbug. 'PI 264453' sorghum was found to be highly resistant, 'Post' and 'Will' barley, 'Amigo' wheat were moderately resistant, and 'Wintermalt' barley, 'Largo', 'DS 28-A', and 'Tam W-101' wheats were highly susceptible (Table 1). Oats 'CI 4888' was moderately

Table 1. Reaction of greenbug biotypes (US) to different host differentials and the damage ratings (0, healthy; 9, dead) by the *PK-1* population of greenbug in a seedling bulk test to various biotype host differentials

Host differential	Reaction of greenbug biotype						
	A	B	C	D	E	F	PK-1
Exotic host differentials							
Sorghum 'PI 264453'	-	R	R	R	R	-	2/R
'Post' barley	-	R	R	R	R	-	4/MR
'Will' barley	-	R	R	R	R	R	4/MR
'Wintermalt' barley	-	S	S	S	S	-	9/S
'Amigo' wheat	-	R	R	R	S	S	6/MR
'Largo' wheat	-	S	R	R	R	R	8/S
'DS 28A' wheat	S	R	S	S	S		9/S
'Tam W-101' wheat	S	S	S	S	S		9/S
Oats 'CI 4888'	-	R	S	S	S	-	5/MR
Oats 'CI 1580'	-	S	R	R	R	MR	3/R
Oats 'CI 1579'	-	S	R	R	R	MR	3/R
Local wheat checks							
'Tandojam-83'							9/S
'WL-711'							9/S
'Faisalabad-83'							9/S

S, susceptible; MR, moderately resistant; R, resistant; -, reaction not known.
Biotype D has the same host plant reaction as biotype C, but it is resistant to organophosphate insecticides.

resistant (damage rating 5), oats 'CI 1579' and oats 'CI 1580' were resistant (damage rating 3). The local susceptible checks ('Tandojam-83, 'WL-711', and 'Faisalabad-83') were found susceptible in this test also (Table 1). Thus it seems that this population behaves some what similar to biotype B but not exactly like this. Therefore, it is designated as biotype PK-1.

5.1.3 Resistance in Recommended Wheat Cultivars

According to variable climatic conditions and cropping patterns, Pakistan has been divided into various wheat zones, and various cultivars are recommended in each zone. At present about 44 wheat varieties are grown in various climatic zones of the country. These wheat varieties were tested in the laboratory for resistance against greenbug.

Firstly a seedling bulk test was conducted to determine the overall resistance in each entry, and then the nature of resistance was determined in selected entries by conducting antixenosis, antibiosis and tolerance tests. The damage occurred to each cultivar in the seedling bulk test is reported in Table 2. Of these varieties, 'Punjab-85' was found to be resistant with a damage rating of 3. 'Faisalabad-85' was moderately resistant with a damage rating of 4. 'PARI-73', 'Sandal' and 'Yecora' had a damage rating of 5 and 'PAK-81', 'WL-711', 'Sutluj-86' and 'Nuri-70' had damage rating of 6 indicating intermediate level of resistance in these cultivars (Table 2). All the remaining varieties, namely, 'LU-26', 'BWP-79', 'C-228' 'C-271', 'C-518', 'C-591', 'Chakwal-86', 'Dirk', 'Khyber-79'

'LYP-73', 'Punjab-81', 'SA-75', 'Sarsabaz', 'ARZ', 'Barani-83', 'Blue Silver', 'C-273', 'Chenab-70', 'Chenab-79', 'Faisalabad-83', 'Khyber-87', 'Kohinoor-83', 'Mexipak', 'Pavon', 'Pirsabak-85', 'Potohar', 'Punjab-76', 'Rawal-87', 'Sind-81', 'Sultan-86', 'Tandojam-83', 'Wadanak-85', 'ZA-77', 'Zamindar-80' and 'Zargoon-79' were found highly susceptible to greenbug with a damage rating of 7 to 9 (Table 2).

Some of the wheat varieties, namely, 'PARI-73', 'WL-711', 'Yecora', 'PAK-81', 'Sind-81', 'Punjab-85', 'Faisalabad-83', 'Faisalabad-85', 'Sandal' and 'Tandojam-83' were tested to determine the nature of resistance in them. Of these 'Punjab-85' was resistant, 'PARI-73', 'WL-711', 'Yecora', 'PAK-81', 'Faisalabad-85' and 'Sandal' were moderately resistant, and 'Sind-81', 'Faisalabad-83' and 'Tandojam-83' were highly susceptible.

In antixenosis test, 'PARI-73', 'WL-711' and 'Yecora' were found to be the least preferred (mean number of greenbugs 1-2/plant), whereas 'Faisalabad-83' and 'Tandojam-83' were found to be the most preferred by the greenbug (mean number of greenbugs 7-8 per plant) (Table 3). This confirms the findings of the previous test. There were no significant differences ($P > 0.05$) among the mean number of greenbugs on 'PARI-73', 'WL-711', 'Yecora', 'PAK-81', 'Sind-81', 'Punjab-85' and 'Sandal'.

The antibiosis test measures the fecundity of the test females on the test host. The lowest number of nymphs (mean 49.0 $\pm$ 9.17 per female) were produced on 'Punjab-85'. However, there

were no significant differences ($P > 0.05$) in the mean number of nymphs produced per female on 'Punjab-85', 'WL-711' (58.30), 'Tandojam-83' (59.90), 'PARI-73' (61.30), 'Faisalabad-83' (61.80), 'PAK-81' (67.0) and 'Faisalabad-85' (67.20). The maximum number of nymphs (76.60 $\pm$ 15.02 per female) were produced on 'Yecora' (Table 4). However, there were no significant ($P > 0.05$) differences in the mean number of nymphs produced per female on 'PAK-81', 'Faisalabad-85', 'Sind-81', 'Sandal' and 'Yecora'. In fact DMRT grouped these means in three overlapping groups. However, it is evident that 'Punjab-85' cultivar has high level of antibiosis.

The tolerance test measures the ability of a plant to withstand the attack of a pest. The mean damage ratings to wheat cultivars after 10 days of infestation in the tolerance test are given in Table 5. In this test the lowest damage was recorded on 'PARI-73' (mean damage rating 4.10 $\pm$ 2.60), followed by 'Sandal' (4.80 $\pm$ 2.0) and 'Punjab-85' (4.8 $\pm$ 2.0) in ascending order. However, the means were not significantly different ($P > 0.05$). The damage rating on 'PAK-81', 'Tandojam-83', 'Yecora', 'WL-711' and 'Faisalabad-83' varied from 5 to 5.8, However, there was no significant ($P > 0.05$) difference in the means of all these cultivars. 'Sind-81' had a damage rating of 7.3 $\pm$ 1.16 and 'Faisalabad-85' had damage rating of 7.4 $\pm$ 1.26, and the means were not significantly different ($P > 0.05$). In this test also, DMRT grouped the mean damage ratings on all these cultivars in three overlapping groups.

Table 2. Resistance in recommended wheat varieties against greenbug

S. No.	Cultivar	Damage Rating
	HIGHLY RESISTANT	
1	'Punjab-85'	3
	MODERATELY RESISTANT	
2	'Faisalabad-85'	4
3	'PARI-73'	5
4	'Sandal'	5
5	'Yecora'	5
6	'PAK-81'	6
7	'WL-711'	6
8	'Sutluj-86'	6
9	'Nuri-70'	6
	SUSCEPTIBLE	
10	'LU-26'	7
11	'BWP-79'	8
12	'C-228'	8
13	'C-271'	8
14	'C-518'	8
15	'C-591'	8
16	'Chakwal-86'	8
17	'Dirk'	8
18	'Khyber-79'	8
19	'Lyp-73'	8
20	'Punjab-81'	8
21	'SA-75'	8
22	'Sarsabaz'	8
23	'ARZ'	9
24	'Barani-83'	9
25	'Blue sliver'	9
26	'C-273'	9
27	'Chenab-70'	9
28	'Chenab-79'	9
29	'Faisalabad-83'	9

S. No.	Cultivar	Damage Rating
30	'Khyber-87'	9
31	'Kohinoor-83'	9
32	'Mexipak'	9
33	'Pavon'	9
34	'Pirsabak-85'	9
35	'Pothowar'	9
36	'Punjab-76'	9
37	'Rawal-87'	9
38	'Sind-81'	9
39	'Sultan-86'	9
40	'Tandojam-83'	9
41	'Wadanak-85'	9
42	'ZA-77'	9
43	'Zamindar-80'	9
44	'Zargoon-79'	9

Table 3. Mean number of greenbugs/plant after 24 hours of release in an antixenosis test

Cultivar	Mean	S.D
'PARI-73'	2.40 a	1.84
'WL-711'	2.50 a	1.78
'Yecora'	2.90 ab	1.97
'Pak-81'	3.20 ab	3.67
'Sind-81'	3.40 abc	2.27
'Punjab-85'	4.20 abc	3.76
'Sandal'	4.30 abc	3.23
'Faisalabad-85'	4.50 abc	2.76
'Faisalabad-83'	7.00 bc	5.44
'Tandojam-83'	7.50 bc	5.32

Means followed by the same letters are not significantly different at P = 0.01. MSE= 12.81, d.f. 81, Reps= 10.

Table 4. Mean number of nymphs produced by greenbug females on various wheat cultivars in an antibiosis test

Cultivar	Mean	S.D
'Punjab-85'	49.00 a	9.17
'WL-711'	58.30 ab	10.55
'Tandojam-83'	59.90 ab	10.57
'PARI-73'	61.30 ab	7.79
'Faisalabad-83'	61.80 ab	7.13
'Pak-81'	67.00 abc	13.53
'Faisalabad-85'	67.20 abc	11.80
'Sind-81'	70.80 bc	17.48
'Sandal'	70.80 bc	14.06
'Yecora'	76.60 c	15.02

Means followed by the same letters are not significantly different at P=0.01. MSE=145.38, d.f. 81, Reps=10.

Table 5. Mean damage rating by greenbug to wheat cultivars after 10 days of infestation at the rate of10 adults/plant

Cultivar	Mean	S.D.
'PARI-73'	4.10 a	2.60
'Sandal'	4.80 a	2.00
'Punjab-85'	4.80 a	2.00
'Pak-81'	5.00 a	2.62
'Yecora'	5.20 ab	1.81
'Tandojam-83'	5.30 abc	1.83
'WL-711'	5.60 abc	1.95
'Faisalabad-83'	5.80 abc	1.55
'Sind-81'	7.30 bc	1.16
'Faisalabad-85'	7.40 c	1.26

Means followed by the same letters are not significantly different at P = 0.01. MSE = 3.15, d.f. 81, Reps = 10.

These three tests, namely, antixenosis, antibiosis and tolerance, indicate that resistance in 'Punjab-85' is mainly due to antibiosis and a low level of tolerance.

5.1.4 Resistance in Wheat Germplasm

Some 481 germplasm lines procured from the Plant Genetic Resources Program, National Agricultural Research Centre, Islamabad, were tested for resistance against greenbug in the laboratory. Of these 42 germplasm lines failed to germinate (Appendix I).

Sixteen germplasm lines were found to have high level of resistance against greenbug. The damage rating on these lines varied from 2 to 3 (0, healthy; 9, dead) (Table 6). These lines were 'PAK 15081', 'PAK 15115', 'PAK 15139', 'PAK 15242', 'PAK 15433', 'PAK 15479', 'PAK 15481', 'PAK 15519', 'PAK 15992', 'PAK 15994', 'PAK 15995', 'PAK 15997', 'PAK 16007', 'PAK 16008', 'PAK 16010' and 'PAK 16190'. These entries were re-tested and were again found to be highly resistant against greenbug.

Of the tested entries 114 were moderately resistant with damage rating 4 to 6 at 0 to 9 damage scale. Of these 29 entries ('PAK 15082', 'PAK 15091', 'PAK 15340', 'PAK 15396', 'PAK 15429', 'PAK 15436', 'PAK 15458', 'PAK 15485', 'PAK 15531', 'PAK 15532', 'PAK 15535', 'PAK 15547', 'PAK 15591', 'PAK 15593', 'PAK 15594', 'PAK 15605', 'PAK 15635', 'PAK 15637', 'PAK 15643', 'PAK 16006', 'PAK 16012', 'PAK 16048', 'PAK 16049', 'PAK 16052', 'PAK 16060', 'PAK 16061', 'PAK 16074', 'PAK 16179', 'PAK 16323') had a damage rating of four, 33 had a damage rating of 5 and 52 had damage

Table 6. Wheat germplasm found resistant against greenbug in seedling bulk test

S. No.	Germplasm	Damage Rating
1	PAK 15081	2
2	PAK 15115	3
3	PAK 15139	3
4	PAK 15242	3
5	PAK 15433	3
6	PAK 15479	3
7	PAK 15481	3
8	PAK 15519	3
9	PAK 15992	3
10	PAK 15994	3
11	PAK 15995	3
12	PAK 15997	3
13	PAK 16007	3
14	PAK 16008	3
15	PAK 16010	3
16	PAK 16190	3

Table 7. Wheat germplasm found moderately resistant against greenbug in seedling bulk test

S. No.	Germplasm	Damage Rating
1	PAK 15082	4
2	PAK 15091	4
3	PAK 15340	4
4	PAK 15396	4
5	PAK 15429	4
6	PAK 15436	4
7	PAK 15458	4
8	PAK 15485	4
9	PAK 15531	4
10	PAK 15532	4
11	PAK 15535	4
12	PAK 15547	4
13	PAK 15591	4
14	PAK 15593	4
15	PAK 15594	4
16	PAK 15605	4
17	PAK 15635	4
18	PAK 15637	4
19	PAK 15643	4
20	PAK 16006	4
21	PAK 16012	4
22	PAK 16048	4
23	PAK 16049	4
24	PAK 16052	4
25	PAK 16060	4
26	PAK 16061	4
27	PAK 16074	4
28	PAK 16179	4
29	PAK 16323	4
30	PAK 15084	5
31	PAK 15088	5
32	PAK 15111	5
33	PAK 15129	5
34	PAK 15191	5
35	PAK 15207	5
36	PAK 15218	5
37	PAK 15432	5
38	PAK 15482	5
39	PAK 15500	5
40	PAK 15502	5
41	PAK 15512	5
42	PAK 15517	5

S. No.	Germplasm	Damage Rating
43	PAK 15527	5
44	PAK 15529	5
45	PAK 15538	5
46	PAK 15561	5
47	PAK 15564	5
48	PAK 15571	5
49	PAK 15584	5
50	PAK 15598	5
51	PAK 15618	5
52	PAK 15619	5
53	PAK 15620	5
54	PAK 15642	5
55	PAK 15643	5
56	PAK 15654	5
57	PAK 15997	5
58	PAK 16041	5
59	PAK 16153	5
60	PAK 16228	5
61	PAK 16230	5
62	PAK 16343	5
63	PAK 15048	6
64	PAK 15103	6
65	PAK 15125	6
66	PAK 15128	6
67	PAK 15320	6
68	PAK 15336	6
69	PAK 15338	6
70	PAK 15339	6
71	PAK 15357	6
72	PAK 15401	6
73	PAK 15422	6
74	PAK 15449	6
75	PAK 15453	6
76	PAK 15457	6
77	PAK 15469	6
78	PAK 15478	6
79	PAK 15484	6
80	PAK 15492	6
81	PAK 15504	6
82	PAK 15508	6
83	PAK 15551	6
84	PAK 15562	6
85	PAK 15583	6
86	PAK 15600	6

S. No.	Germplasm	Damage Rating
87	PAK 15601	6
88	PAK 15623	6
89	PAK 15625	6
90	PAK 15641	6
91	PAK 15652	6
92	PAK 15654	6
93	PAK 15656	6
94	PAK 15663	6
95	PAK 15665	6
96	PAK 16005	6
97	PAK 16021	6
98	PAK 16041	6
99	PAK 16042	6
100	PAK 16043	6
101	PAK 16063	6
102	PAK 16064	6
103	PAK 16075	6
104	PAK 16091	6
115	PAK 16099	6
116	PAK 16150	6
117	PAK 16159	6
118	PAK 16176	6
119	PAK 16200	6
110	PAK 16231	6
111	PAK 16295	6
112	PAK 16429	6
113	PAK 16438	6
114	PAK 16481	6

rating of 6 (Table 7).

Of the tested entries, 309 were found highly susceptible to greenbug with damage rating of 7 to 9. Of these 78 entries had damage rating of seven, 108 entries had damage rating of eight, and 123 entries had a damage rating of 9 at 0 (healthy) to 9 (dead) damage scale (Table 8).

5.1.5 Resistance in Barley Germplasm

Some 81 barley germplasm lines were tested in the laboratory to determine their resistance against greenbug. Of these 8 lines had high level of resistance with damage rating of 2 to 3 (Table 9). These were 'PAK 30095', 'PAK 30101', 'PAK 30104', 'PAK 30128', 'PAK 30133', 'BA-1 2', 'BYT (MRA) 9', and 'BYT (MRA) 11' (Table 9). These lines were re-tested and were again found to be resistant.

Twenty-one lines were found to be moderately resistant to greenbug with damage rating of 4 to 6 (Table 10). Of these, 'PAK 30055', 'PAK 30093', 'PAK 30115', 'PAK 30121', 'PAK 30125', 'PAK 30130', 'PAK 30260', 'PAK 30262', and 'BYT (MRA)2' had a damage rating of 4, indicating moderate level of resistance. 'PAK 30094', 'PAK 30097', 'PAK 30141', and 'BYT-4' had damage rating of 5; and 'PAK 30099', 'PAK 30159', 'PAK 30183', 'PAK 30259', 'PAK 30261', 'BYT (MRA) 12', 'BYT (MRA) 13', and 'BYT (MRA) 14' had damage rating of 6 (Table 10).

Fifty-two germplasm lines were found to be susceptible to greenbug (Table 11). Of these 18 lines had a damage rating of

Table 8. Wheat germplasm found susceptible against greenbug in seedling bulk test

S. No.	Germplasm	Damage Rating
1	PAK 15099	7
2	PAK 15113	7
3	PAK 15206	7
4	PAK 15318	7
5	PAK 15319	7
6	PAK 15368	7
7	PAK 15372	7
8	PAK 15408	7
9	PAK 15416	7
10	PAK 15419	7
11	PAK 15437	7
12	PAK 15445	7
13	PAK 15446	7
14	PAK 15447	7
15	PAK 15448	7
16	PAK 15463	7
17	PAK 15471	7
18	PAK 15475	7
19	PAK 15480	7
20	PAK 15491	7
21	PAK 15496	7
22	PAK 15509	7
23	PAK 15520	7
24	PAK 15528	7
25	PAK 15542	7
26	PAK 15543	7
27	PAK 15544	7
28	PAK 15548	7
29	PAK 15552	7
30	PAK 15559	7
31	PAK 15560	7
32	PAK 15563	7
33	PAK 15568	7
34	PAK 15572	7
35	PAK 15578	7
36	PAK 15585	7
37	PAK 15609	7
38	PAK 15610	7
39	PAK 15613	7
40	PAK 15615	7
41	PAK 15622	7
42	PAK 15631	7

S. No.	Germplasm	Damage Rating
43	PAK 15648	7
44	PAK 15649	7
45	PAK 15660	7
46	PAK 15686	7
47	PAK 15970	7
48	PAK 15975	7
49	PAK 15978	7
50	PAK 15981	7
51	PAK 15993	7
52	PAK 15999	7
53	PAK 16004	7
54	PAK 16018	7
55	PAK 16022	7
56	PAK 16023	7
57	PAK 16039	7
58	PAK 16046	7
59	PAK 16047	7
60	PAK 16051	7
61	PAK 16055	7
62	PAK 16057	7
63	PAK 16059	7
64	PAK 16071	7
65	PAK 16152	7
66	PAK 16162	7
67	PAK 16181	7
68	PAK 16182	7
69	PAK 16185	7
70	PAK 16212	7
71	PAK 16225	7
72	PAK 16297	7
73	PAK 16327	7
74	PAK 16342	7
75	PAK 16418	7
76	PAK 16432	7
77	PAK 16433	7
78	PAK 16475	7
79	PAK 15085	8
80	PAK 15146	8
81	PAK 15278	8
82	PAK 15136	8
83	PAK 15326	8
84	PAK 15341	8
85	PAK 15358	8

S. No.	Germplasm	Damage Rating
87	PAK 15373	8
88	PAK 15376	8
89	PAK 15378	8
90	PAK 15384	8
91	PAK 15406	8
92	PAK 15409	8
93	PAK 15414	8
94	PAK 15434	8
95	PAK 15435	8
96	PAK 15443	8
97	PAK 15450	8
98	PAK 15467	8
99	PAK 15468	8
100	PAK 15469	8
101	PAK 15472	8
102	PAK 15474	8
103	PAK 15476	8
104	PAK 15489	8
105	PAK 15022	8
106	PAK 15514	8
107	PAK 15523	8
108	PAK 15526	8
109	PAK 15534	8
110	PAK 15546	8
111	PAK 15554	8
112	PAK 15557	8
113	PAK 15558	8
114	PAK 15560	8
115	PAK 15573	8
116	PAK 15578	8
117	PAK 15579	8
118	PAK 15580	8
119	PAK 15582	8
120	PAK 15587	8
121	PAK 15592	8
122	PAK 15596	8
123	PAK 15603	8
124	PAK 15606	8
125	PAK 15611	8
126	PAK 15601	8
127	PAK 15612	8
128	PAK 15613	8
129	PAK 15614	8
130	PAK 15623	8
131	PAK 15626	8

S. No.	Germplasm	Damage Rating
132	PAK 15627	8
133	PAK 15628	8
134	PAK 15632	8
135	PAK 15633	8
136	PAK 15634	8
137	PAK 15639	8
138	PAK 15641	8
139	PAK 15642	8
140	PAK 15651	8
141	PAK 15653	8
142	PAK 15657	8
143	PAK 15658	8
144	PAK 15659	8
145	PAK 15662	8
146	PAK 15663	8
147	PAK 15664	8
148	PAK 15665	8
149	PAK 15955	8
150	PAK 15959	8
151	PAK 15968	8
152	PAK 15969	8
153	PAK 15971	8
154	PAK 15976	8
155	PAK 16013	8
156	PAK 16016	8
157	PAK 16037	8
158	PAK 16038	8
159	PAK 16044	8
160	PAK 16053	8
161	PAK 16054	8
162	PAK 16056	8
163	PAK 16058	8
164	PAK 16080	8
165	PAK 16081	8
166	PAK 16086	8
167	PAK 16151	9
168	PAK 16160	8
169	PAK 16169	8
170	PAK 16174	8
171	PAK 16180	8
172	PAK 16202	8
173	PAK 16221	8
174	PAK 16227	8
175	PAK 16229	8
176	PAK 16294	8

S. No.	Germplasm	Damage Rating
177	PAK 16310	8
178	PAK 16320	8
179	PAK 16340	8
180	PAK 16443	8
181	PAK 16456	8
182	PAK 16457	8
183	PAK 16464	8
184	PAK 16492	8
185	PAK 16493	8
186	PAK 16575	8
187	PAK 15086	9
188	PAK 15087	9
189	PAK 15092	9
190	PAK 15109	9
291	PAK 15112	9
292	PAK 15131	9
293	PAK 15133	9
294	PAK 15198	9
295	PAK 16220	9
296	PAK 15249	9
297	PAK 15304	9
298	PAK 15345	9
299	PAK 15348	9
200	PAK 15356	9
201	PAK 15366	9
202	PAK 15367	9
203	PAK 15379	9
204	PAK 15416	9
205	PAK 15424	9
206	PAK 15442	9
207	PAK 15444	9
208	PAK 15459	9
209	PAK 15460	9
210	PAK 15470	9
211	PAK 15477	9
212	PAK 15481	9
213	PAK 15505	9
214	PAK 15521	9
215	PAK 15528	9
216	PAK 15530	9
217	PAK 15536	9
218	PAK 15548	9
219	PAK 15549	9

S. No.	Germplasm	Damage Rating
220	PAK 15550	9
221	PAK 15555	9
222	PAK 15556	9
223	PAK 15563	9
224	PAK 15567	9
225	PAK 15569	9
226	PAK 15573	9
227	PAK 15575	9
228	PAK 15576	9
229	PAK 15579	9
230	PAK 15581	9
231	PAK 15583	9
232	PAK 15595	9
233	PAK 15597	9
234	PAK 15602	9
235	PAK 15604	9
236	PAK 15607	9
237	PAK 15608	9
238	PAK 15614	9
239	PAK 15616	9
240	PAK 15617	9
241	PAK 15621	9
242	PAK 15624	9
243	PAK 15625	9
244	PAK 15629	9
245	PAK 15630	9
246	PAK 15637	9
247	PAK 15639	9
248	PAK 15640	9
249	PAK 15644	9
250	PAK 15645	9
251	PAK 15646	9
252	PAK 15647	9
253	PAK 15650	9
254	PAK 15652	9
255	PAK 15655	9
256	PAK 15656	9
257	PAK 15657	9
258	PAK 15659	9
259	PAK 15661	9
260	PAK 15664	9
261	PAK 15666	9
262	PAK 15668	9
263	PAK 15900	9
264	PAK 15952	9

S. No.	Germplasm	Damage Rating
265	PAK 15953	9
266	PAK 15957	9
267	PAK 15958	9
268	PAK 15961	9
269	PAK 15962	9
270	PAK 15963	9
271	PAK 15964	9
272	PAK 15965	9
273	PAK 15966	9
274	PAK 15967	9
275	PAK 15972	9
276	PAK 15973	9
277	PAK 15974	9
278	PAK 15980	9
279	PAK 16000	9
280	PAK 16002	9
281	PAK 16003	9
282	PAK 16014	9
283	PAK 16033	9
284	PAK 16034	9
285	PAK 16035	9
286	PAK 16036	9
287	PAK 16062	9
288	PAK 16072	9
289	PAK 16073	9
290	PAK 16093	9
291	PAK 16094	9
292	PAK 16098	9
293	PAK 16147	9
294	PAK 16149	9
295	PAK 16165	9
296	PAK 16184	9
297	PAK 16188	9
298	PAK 16189	9
299	PAK 16196	9
290	PAK 16199	9
291	PAK 16204	9
292	PAK 16208	9
293	PAK 16209	9
294	PAK 16222	9
295	PAK 16232	9
296	PAK 16300	9
297	PAK 16314	9
298	PAK 16339	9
299	PAK 16341	9

S. No.	Germplasm	Damage Rating
300	PAK 16437	9
301	PAK 16440	9
302	PAK 16459	9
303	PAK 16460	9
304	PAK 16461	9
305	PAK 16468	9
306	PAK 16477	9
307	PAK 16494	9
308	PAK 16495	9
309	PAK 16935	9

Table 9. Barley germplasm lines found resistant against greenbug in seedling bulk test.

S. No.	Germplasm	Damage Rating
1	PAK 30095	3
2	PAK 30101	2
3	PAK 30104	3
4	PAK 30128	3
5	PAK 30133	3
6	BA-1 2	3
7	BYT (MRA) 9	3
8	BYT (MRA) 11	3

Table 10. Barley germplasm lines found moderately resistant against greenbug in a seedling bulk test

S. N.	Germplasm	Damage Rating
1	PAK 30055	4
2	PAK 30093	4
3	PAK 30115	4
4	PAK 30121	4
5	PAK 30125	4
6	PAK 30130	4
7	PAK 30260	4
8	PAK 30262	4
9	BYT (MRA)	4
10	PAK 30094	5
11	PAK 30097	5
12	PAK 30141	5
13	BYT-4	5
14	PAK 30099	6
15	PAK 30159	6
16	PAK 30183	6
17	PAK 30259	6
18	PAK 30261	6
19	BYT (MRA) 12	6
20	BYT (MRA) 13	6
21	BYT (MRA) 14	6

seven, 19 had damage rating of 8 and 15 had damage rating of 9 (Table 11).

Six germplasm lines failed to germinate (Appendix II).

5.1.6 Resistance in Sorghum Germplasm

Some 184 sorghum germplasm lines were tested in the laboratory for resistance against greenbug. Of these five lines, namely 'PAK 80043', 'PAK 80044', 'PAK 80255', 'PAK 80303' and 'PAK 80305', were found to be highly resistant. The damage ratings for these entries were, respectively, 3, 3, 2, 2, and 2 (Table 12). These lines were re-tested and were found to be highly resistant.

Forty-one germplasm lines were found to be moderately resistant. Of these 8 lines, namely, 'PAK 80035', 'PAK 80038', 'PAK 80039', 'PAK 80040', 'PAK 80045', 'PAK 80075', 'PAK 80118', and 'PAK 80308', had a damage rating of 4 (Table 13). Fourteen lines had a damage rating of five, and 19 lines had a damage rating of 6 (Table 13).

Some 138 sorghum lines were found to be highly susceptible against greenbug. Of these, 37 lines had a damage rating of seven, 30 had a damage rating of eight, and 71 had a damage rating of 9 (Table 13).

5.1.7 Resistance in Pearl Millet Germplasm

Greenbug also attacks on millets. Although millets is not included in the approved plan of the project, some 36 germplasm

Table 11. Barley germplasm found susceptible resistant against greenbug in a seedling bulk test

S. No.	Germplasm	Damage Rating
1	PAK 30001	7
2	PAK 30117	7
3	PAK 30140	7
4	PAK 30249	7
5	PAK 30254	7
6	B-83010	7
7	B-83052	7
8	B-83068	7
9	BA-1-3	7
10	BA-1-5	7
11	BA-1-8	7
12	BA-1-10	7
13	BYT-3	7
14	BYT-4	7
15	BYT (MRA)-6	7
16	BYT (MRA)-10	7
17	BYT (MRA)-21	7
18	BYT (MRA)-22	7
19	PAK 30151	8
20	PAK 30154	8
21	PAK 30161	8
22	PAK 30181	8
23	PAK 30247	8
24	PAK 30248	8
25	PAK 30252	8
26	PAK 30253	8
27	PAK 30267	8
28	PAK 30271	8
29	PAK 30278	8
30	BA-1-7	8
31	BYT-1	8
32	BYT-2	8
33	BYT-9	8
34	BYT-11	8
35	BYT-16	8
36	BYT (MRA)-24	8
37	JAU-87	8
38	PAK 30142	9
39	PAK 30162	9
40	PAK 30163	9

S. N.	Germplasm	Damage Rating
41	PAK 30164	9
42	PAK 30165	9
43	PAK 30171	9
44	PAK 30172	9
45	PAK 30179	9
46	PAK 30253	9
47	PAK 30264	9
48	PAK 30265	9
49	PAK 30269	9
50	BA-1-4	9
51	BYT (MRA)-5	9
52	BYT (MRA)-23	9

Table 12. Sorghum germplasm lines found resistant against greenbug

S. No.	Germplasm	Damage Rating
1	PAK 80043	3
2	PAK 80044	3
3	PAK 80255	2
4	PAK 80303	2
5	PAK 80305	2

Table 13. Sorghum germplasm lines found moderately resistant against greenbug

S. No.	Germplasm	Damage Rating
1	PAK 80035	4
2	PAK 80038	4
3	PAK 80039	4
4	PAK 80040	4
5	PAK 80045	4
6	PAK 80075	4
7	PAK 80118	4
8	PAK 80308	4
9	PAK 80036	5
10	PAK 80041	5
11	PAK 80046	5
12	PAK 80050	5
13	PAK 80055	5
14	PAK 80074	5
15	PAK 80078	5
16	PAK 80106	5
17	PAK 80115	5
18	PAK 80116	5
19	PAK 80119	5
20	PAK 80180	5
21	PAK 80231	5
22	PAK 80304	5
23	PAK 80037	6
24	PAK 80057	6
25	PAK 80062	6
26	PAK 80083	6
27	PAK 80107	6
28	PAK 80113	6
29	PAK 80114	6
30	PAK 80117	6
31	PAK 80149	6
32	PAK 80153	6
33	PAK 80154	6
34	PAK 80155	6
35	PAK 80181	6
36	PAK 80182	6
37	PAK 80215	6
38	PAK 80250	6
39	PAK 80251	6
40	PAK 80271	6
41	PAK 80311	6

Table 14. Sorghum germplasm lines found susceptible to greenbug

S. No.	Germplasm	Damage Rating
1	PAK 80026	7
2	PAK 80048	7
3	PAK 80068	7
4	PAK 80070	7
5	PAK 80077	7
6	PAK 80079	7
7	PAK 80082	7
8	PAK 80084	7
9	PAK 80086	7
10	PAK 80090	7
11	PAK 80109	7
12	PAK 80156	7
13	PAK 80158	7
14	PAK 80159	7
15	PAK 80164	7
16	PAK 80167	7
17	PAK 80168	7
18	PAK 80175	7
19	PAK 80184	7
20	PAK 80185	7
21	PAK 80186	7
22	PAK 80187	7
23	PAK 80201	7
24	PAK 80209	7
25	PAK 80216	7
26	PAK 80217	7
27	PAK 80229	7
28	PAK 80236	7
29	PAK 80249	7
30	PAK 80250	7
31	PAK 80252	7
32	PAK 80256	7
33	PAK 80257	7
34	PAK 80268	7
35	PAK 80306	7
36	PAK 80310	7
37	PAK 80312	7
38	PAK 80051	8
39	PAK 80076	8
40	PAK 80088	8
41	PAK 80110	8
42	PAK 80112	8
43	PAK 80120	8

S. No.	Germplasm	Damage Rating
44	PAK 80165	8
45	PAK 80178	8
46	PAK 80179	8
47	PAK 80197	8
48	PAK 80199	8
49	PAK 80205	8
50	PAK 80206	8
51	PAK 80208	8
52	PAK 80210	8
53	PAK 80212	8
54	PAK 80220	8
55	PAK 80222	8
56	PAK 80243	8
57	PAK 80245	8
58	PAK 80247	8
59	PAK 80248	8
60	PAK 80251	8
61	PAK 80252	8
62	PAK 80253	8
63	PAK 80264	8
64	PAK 80266	8
65	PAK 80267	8
66	PAK 80302	8
67	PAK 80307	8
68	PAK 80028	9
69	PAK 80029	9
70	PAK 80032	9
71	PAK 80033	9
72	PAK 80034	9
73	PAK 80056	9
74	PAK 80063	9
75	PAK 80064	9
76	PAK 80066	9
77	PAK 80071	9
78	PAK 80085	9
79	PAK 80087	9
80	PAK 80089	9
81	PAK 80100	9
82	PAK 80111	9
83	PAK 80150	9
84	PAK 80151	9
85	PAK 80152	9
86	PAK 80157	9
87	PAK 80160	9

S. No.	Germplasm	Damage Rating
88	PAK 80161	9
89	PAK 80162	9
90	PAK 80163	9
91	PAK 80166	9
92	PAK 80170	9
93	PAK 80171	9
94	PAK 80172	9
95	PAK 80173	9
96	PAK 80174	9
97	PAK 80176	9
98	PAK 80177	9
99	PAK 80183	9
100	PAK 80188	9
101	PAK 80189	9
102	PAK 80190	9
103	PAK 80191	9
104	PAK 80192	9
105	PAK 80193	9
106	PAK 80194	9
107	PAK 80195	9
108	PAK 80196	9
109	PAK 80197	9
110	PAK 80198	9
111	PAK 80199	9
112	PAK 80200	9
113	PAK 80204	9
114	PAK 80213	9
115	PAK 80214	9
116	PAK 80219	9
117	PAK 80221	9
118	PAK 80223	9
119	PAK 80224	9
120	PAK 80225	9
121	PAK 80230	9
122	PAK 80234	9
123	PAK 80237	9
124	PAK 80238	9
125	PAK 80239	9
126	PAK 80242	9
127	PAK 80244	9
128	PAK 80246	9
129	PAK 80247	9
130	PAK 80253	9
131	PAK 80254	9
132	PAK 80260	9

S. No.	Germplasm	Damage Rating
133	PAK 80263	9
134	PAK 80264	9
135	PAK 80272	9
136	PAK 80300	9
137	PAK 80301	9
138	PAK 80313	9

lines were tested in the laboratory for resistance against greenbug. Of these 3 lines, namely, 'PAK 75060', 'PAK 75076' and 'PAK 75081' were highly resistant with a damage rating of 3 (Table 15). These lines were re-tested and were found to be resistant in the second test also.

Some 20 lines were found to be moderately resistant (Table 16). 'PAK 75079' had a damage rating of 4. Nine lines, namely, 'PAK 75043', 'PAK 75045', 'PAK 75046', 'PAK 75049', 'PAK 75054', 'PAK 75059', 'PAK 75061', 'PAK 75063', and 'PAK 75080' had a damage rating of 5. The entries 'PAK 75038', 'PAK 75040', 'PAK 75042', 'PAK 75044', 'PAK 75048', 'PAK 75050', 'PAK 75052', 'PAK 75058', 'PAK 75062' and 'PAK 75174' had a damage rating of 6 (Table 16).

Thirteen lines were found to be susceptible to greenbug. Of these 8 lines had a damage rating of seven, 1 had a damage rating of eight, and 4 entries had a damage rating of 9 (Table 17).

5.2 Bird Cherry-Oat Aphid

Bird Cherry-Oat aphid is also not included in the approved plan of work. As it is a serious pest of cereals in Pakistan, the recommended wheat cultivars were tested for resistance against this pest also. Among the 43 test wheat cultivars in the seedling bulk test, 4 entries were found to be highly resistant (damage rating less than 3), 13 entries were found moderately resistant (damage rating 4-6) while 26 entries were found highly susceptible (damage rating 7-9) (Table 18-20).

Table 15. Pearl millet germplasm lines found resistant against greenbug

S. No.	Germplasm	Damage Rating
1	PAK 75060	3
2	PAK 75076	3
3	PAK 75081	3

Table 16. Pearl millets germplasm lines found moderately resistant against greenbug

S. No.	Germplasm	Damage Rating
1	PAK 75079	4
2	PAK 75043	5
3	PAK 75045	5
4	PAK 75046	5
5	PAK 75049	5
6	PAK 75054	5
7	PAK 75059	5
8	PAK 75061	5
9	PAK 75063	5
10	PAK 75080	5
11	PAK 75038	6
12	PAK 75040	6
13	PAK 75042	6
14	PAK 75044	6
15	PAK 75048	6
16	PAK 75050	6
17	PAK 75052	6
18	PAK 75058	6
19	PAK 75062	6
20	PAK 75174	6

Table 17. Pearl millet germplasm lines found susceptible to greenbug

S. No.	Germplasm	Damage Rating
1	PAK 75041	7
2	PAK 75047	7
3	PAK 75053	7
4	PAK 75055	7
5	PAK 75057	7
6	PAK 75064	7
7	PAK 75069	7
8	PAK 75070	7
9	PAK 75073	8
10	PAK 75065	9
11	PAK 75072	9
12	PAK 75077	9
13	PAK 75078	9

The variety 'Faisalabad-85', 'PARI-73', 'Rawal-87' and 'Punjab 81' were found to be highly resistant (Table 18). The damage rating to each cultivar was from 2 to 3. The cultivar 'WL-711', 'Yecora', 'Kohinoor-83', 'Sandal', 'Pirsabak-85', 'Tandojam-83', 'PAK-81', 'Pavon', 'Mexipak', 'SA-75', 'ARZ', 'BWP-87' and 'Lyallpur-73' were found to be moderately resistant (Table 19). The damage rating varied from 4 to 5. The cultivar 'C-273', 'Sind-81', 'ZA-77', 'Punjab-85', 'Faisalabad-83', 'Wadanak', 'Barani-83', 'Sarsabaz', 'C-591', 'Zamindar-81', 'C-217', 'LU-26', 'Nuri-70', 'Dirk', 'C-228', 'Blue silver', 'Sutluj-86', 'C-518', 'Chenab-70', 'C-271', 'Zargoon-79', 'Chenab-79', 'Potohar', 'Khyber-79', 'Chakwal-86' and 'Khyber-87' were found to be susceptible with damage rating to each cultivar from 6 to 9 (Table 20).

Some of the oats, barley and wheat cultivars which are used as biotype differentials in the USA were also tested for resistance against bird cherry-oat aphid. Wheat cultivars 'DS-28A', 'Largo', 'Tam W-101' and 'Wintermalt' barley were found to be highly susceptible. The barley varieties, 'Will' and 'Post', and 'Amigo' wheat were found to be highly resistant, whereas oats 'CI 1579' and 'CI 1580' were found to be moderately resistant (Table 21).

Table 18. Wheat cultivars with high level of resistance against bird cherry-oat aphid

S. No.	Cultivar	Damage rating
1	'Faisalabad-85'	3
2	'PARI-73'	2
3	'Rawal-87'	2
4	'Punjab-81'	3

Table 19. Wheat cultivars with moderate level of resistance against bird cherry-oat aphid

S. No.	Cultivar	Damage rating
1	'WL-711'	5
2	'Yecora'	4
3	'Kohinoor-83'	4
4	'Sandal'	5
5	'Pirsabak-85'	5
6	'Tandojam-83'	6
7	'Pak-81'	4
8	'Pavon'	4
9	'Mexipak'	4
10	'SA-75'	5
11	'ARZ'	4
12	'BWP-87'	4
13	'Lyallpur-73'	4

Table 20. Wheat cultivars found highly susceptible against bird cherry-oat aphid

S. No.	Cultivar	Damage rating
1	'C-273'	7
2	'Sind-81'	9
3	'ZA-77'	7
4	'Punjab-85'	7
5	'Faisalabad-83'	7
6	'Wadanak'	9
7	'Barani-83'	8
8	'Sarsabez'	8
9	'C-591'	8
10	'Zamindar-81'	9
11	'C-217'	9
12	'LU-26'	8
13	'Nuri-70'	7
14	'Dirk'	9
15	'C-228'	9
16	'Blue silver'	8
17	'Sutluj-86'	8
18	'C-518'	7
19	'Chenab-70'	8
20	'C-271'	9
21	'Zargoon'	7
22	'Chenab-79'	9
23	'Pothowar'	9
24	'Khyber-79'	8
25	'Chakwal-86'	7
26	'Khyber-87'	8

Table 21. Resistance in some exotic small grain entries against bird cherry-oat aphid

S. No.	Test entry	Damage rating
1	Oats 'CI 1579	4
2	Oats 'CI 1580	5
3	'DS-28A' wheat	8
4	'Will' barley	2
5	'Post' barley	2
6	'Wintermalt' barley	9
7	'Largo' wheat	9
8	'Tam W-101' wheat	7
9	'Amigo' wheat	3

6.0 DISCUSSION AND CONCLUSIONS

During the present studies greenbug was collected in high numbers at Malkot (Murree) (density 114 adults/25 plants) and at Sher Shah (Multan) (33 adults/25 plants). However, it was found in small numbers at many locations in the Punjab and NWFP. Since greenbug is an efficient vector of BYDM virus, only a few individuals are required to kill the host plant. Montllor and Gildow (1986) have reported that greenbug fed better than bird cherry-oat aphid on BYDM infected oats, and further the rate of population growth of greenbug was higher on BYDM infected hosts as compared on the healthy hosts. Similar results are reported by Fereres et al. (1989) with grain aphid. It implies that outbreaks of these aphid species can occur in areas where BYDM is present.

Greenbug attacks on sorghum (summer host) as well as small grains, namely, wheat, barley and oats (winter hosts) According to Hamid (1983) at Parachinar it damaged 4.4% plants in June and its population continued to increase, and was at peak in September (200 aphids/plant). At Swat wheat plant infestation was 5% (density 2 grain aphids, 10 greenbugs/plant) in November, 9% in December (density 8 grain aphids, 7 greenbugs/plant), 12% (density 30 grain aphids, 10 greenbugs/plant) in January, 18% (density 120 grain aphids, 30 greenbugs/plant) in February, 21% (density 125 grain aphids, 50 greenbugs/plant) in March, and 32%

(density 112 grain aphids, 9 greenbugs/plant) in April. At Hyderabad the infestation was 12% (density 61 bird cherry- oat aphids, 27 corn leaf aphids and 72 greenbugs/plant). At here the infestation was 5% with 35 greenbugs/plant in March.

The local cultivars and germplasm of wheat, barley, sorghum and pearl millet have not been evaluated before, therefore, the results cannot be compared. Hamid (1983) reported higher populations of greenbug on 'mexipak' than on other varieties ('C-591', 'C-518', 'Chenab-70', 'Barani-70', 'SA-42' and 'Khushal') (186 vs. 16 aphids per 100 plants) in the field. Further the infestation was higher on the crop which received fertilizer. Daniels and Porter (1956) have also reported that high nitrogen levels in the soil and increased plant vigor results in high greenbug populations. Recently Dorschner et al. (1987) have demonstrated that the virulent greenbugs modify the plant metabolism and more free amino acids are available in the attacked plant for further development of the aphids.

Wiktelius and Pettersson (1985) conducted population simulation studies with bird cherry-oat aphid, and concluded that ideal cereals resistant to this species should (i) cause high nymphal mortality; (ii) cause prolonged development of the aphid during early plant stages, and (iii) cause low birth rate close to ear emergence, which means the mechanism of resistance should be antibiosis. However, if the mechanism of resistance is antibiosis, chances of the occurrence of new biotype become higher. Thus tolerance is the ideal mechanism of resistance as there is no selection pressure on the aphids. The present

studies revealed that resistance in 'Punjab-85' is due to antibiosis and low level of tolerance.

The present population of greenbug (collected from Charsadda) responded to various US biotype host differentials in a very different manner as compared with the host reaction of US biotypes A through F. Therefore, this population has been designated as PK-1 for further reference. The local cultivars found susceptible and resistant to PK-1 have been sent to USDA-ARS Plant Science Research Facility, Stillwater, Oklahoma, for testing against the US biotypes. The resistance in wheat against greenbug is monogenic, and occurrence of biotypes is a threat to wheat breeding program. Recently Tyler et al. (1987b) have demonstrated that the greenbug resistance genes present in 5 germplasm lines are all distinct from one another. They have designated Gb1, Gb2, Gb3, Gb4, and Gb5 for the genes present in 'DS-28A', 'Amigo', 'Largo', 'CI 17959' and 'CI 17882' respectively. The entries found resistant in Pakistan may have new gene(s) for resistance, which can be exploited in the breeding programs.

7.0 FUTURE PLAN OF WORK

The local wheat, barley, sorghum and millets germplasm have been screened for resistance against greenbug. Mr. Ata-ul-Mohsin, Scientific Officer, is working on the morphological and morphometric variation within greenbug biotypes. Efforts will be made to:

1. Determine the level of resistance in selected entries against other cereal aphids.

2. Determine the nature and mechanism of resistance in selected entries.

3. Determine the population densities of cereal aphids at selected sites.

4. Determine the geographic variability among the greenbug populations occurring in different ecological zones of Pakistan.

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Appendix I. Wheat gerplasm lines which failed to germinate

S. No.	Germplasm
1	PAK 15093
2	PAK 15094
3	PAK 15097
4	PAK 15100
5	PAK 15116
6	PAK 15132
7	PAK 15135
8	PAK 15139
9	PAK 15150
10	PAK 15162
11	PAK 15163
12	PAK 15166
13	PAK 15167
14	PAK 15258
15	PAK 15259
16	PAK 15264
17	PAK 15301
18	PAK 15439
19	PAK 15440
20	PAK 15441
21	PAK 15466
22	PAK 15488
23	PAK 15497
24	PAK 15503
25	PAK 15506
26	PAK 15510
27	PAK 15517
28	PAK 15522
29	PAK 16059
30	PAK 16161
31	PAK 16175
32	PAK 16177
33	PAK 16193
34	PAK 16201
35	PAK 16205
36	PAK 16207
37	PAK 16215
38	PAK 16299
39	PAK 16313
40	PAK 16321
41	PAK 16442
42	PAK 16476

Appendix II. Balrey germplasm lines which failed to germinate

S. No.	Germplasm
1	PAK 30122
2	PAK 30150
3	PAK 30153
4	PAK 30178
5	PAK 30185
6	PAK 30266

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EVALUATION OF WHEAT, BARLEY AND SORGHUM FOR RESISTANCE AGAINST GREENBUG, *SCHIZAPHIS GRAMINUM* (RONDANI)

Principal Investigator

Dr. C. Inayatullah
National Agricultural Research Centre
Islamabad

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BACKGROUND AND RATIONALE

A number of aphid species attack on cereals in the world. These cause damage by (i) extraction of plant sap, (ii) injection of toxic secretions while feeding, and (iii) transmission of viral diseases. In early 1980's a survey was conducted in Pakistan and aphid species recorded were: *Forda formicaria* von Heyden and *Melanaphis sacchari* on sorghum; *Myzus obtusirostris* David, Narayanan and Rajasingh on corn *(Zea mays* L.); corn leaf aphid, *Rhopalosiphum maidis* (Fitch), on wheat and sorghum; bird cherry-oat aphid, *Rhopalosiphum padi* (L.), on wheat and corn; greenbug, *Schizaphis graminum* (Rondani), on wheat, barely and sorghum; *Sipha maydis* Passerini, on wheat, barley, sorghum and corn; and grain aphid, *Sitobion avenae* (Fabricius), on wheat and barley. Recently a survey has been conducted in Pakistan and at least 45 species of aphids attacking on shoots and roots of grasses have been recorded.

The greenbug is a cosmopolitan pest of many graminaceous crops, especially small grains and sorghum. It has been recorded from 46 countries. In Pakistan the cereal aphids were not considered as pests until about 2 decades ago. In Pakistan low-yielding native cultivars of wheat are being replaced with high-yielding cultivars developed from crosses with 'Mexican' strains, while new hybrids of sorghum and corn have been introduced from USA. Most of the 'Mexican' cultivars are susceptible to greenbug. These new cultivars with different genetic make-up present new situations for greenbug and other aphids, and therefore, create new problems. The use of resistant cultivars is an effective and efficient tool for the control of cereal aphids. Thus the present studies were initiated to evaluate the local wheat, barley, sorghum and pearl millet cultivars and germplasm for resistance against greenbug.

PROGRESS ACHIEVED

The present studies were initiated in August, 1989. Culture of the greenbug collected from Charsadda was established on wheat cultivar 'Faisalabad-83' at 27$\pm$ 2 °C, 60% RH and 16:8 hr day:light regime.

Biotypic Status of Greenbug in Pakistan

A seedling bulk test was conducted with the local and exotic host cultivars obtained from USDA-ARS, Plant Science Research Facility, Stillwater, Oklahoma, to determine the biotype status of the greenbug found in Charsadda so as to

compare the results with the biotypes found in the USA. In the USA 6 biotypes (designated A through F) are found.

One row of each test entry was sown in a metal tray measuring 51 x 35 x 9 cm. There were about 20 seedlings in a row. When the seedlings were about 5 cm high, greenbugs were released on the seedlings at the rate of about 10 greenbugs per seedling. There were 5 replications in this test. The greenbugs were allowed to develop. The plants were observed daily and if infestation level declined more greenbugs were added. After 10 days of infestation, the damage occurred to each entry was visually recorded at 0 to 9 damage scale (0, healthy; 9, dead). The entries were classified as resistant (damage rating 0 to 3), moderately resistant (damage rating 4 to 6) or susceptible (damage rating > 6).

Biotypes A and B are dark green in color with about 1/4 of the cornicle black tipped, whereas biotypes C, D and E are pale green in color, slightly elongated than A or B with cornicle green or only extremity black. Biotype F is similar to biotype A but without the dorsal stripe. These biotypes are differentiated on the basis of their reaction to various hosts. 'PI 264453' sorghum, 'Post' and 'Will' barley are resistant to all the biotypes B through E. 'Wintermalt' barley is susceptible to all the biotypes B through E. 'Amigo' wheat is resistant to biotypes B, C and D, whereas it is susceptible to biotype E. 'Largo' wheat is susceptible to biotype B but it is resistant to biotypes C, D and E. 'DS 28A' wheat is resistant to biotype B, whereas it is susceptible to all the other biotypes. 'Tam W-101' is susceptible to all the biotypes. Oats 'CI 1579' and 'CI 1580' are susceptible to biotype A, but resistant to biotype B through E. Oats 'CI 4888' is resistant to biotype B but susceptible to C and E. 'DS 28-A' wheat is highly resistant to biotype F whereas it is susceptible to biotype A. Oats 'CI 1579' and 'CI 1580' show intermediate resistance to biotype F. Biotype D behaves like biotype C except that it is resistant to some of the organophosphate insecticides.

During the present studies these host differentials showed very interesting results to the present population of greenbug. 'PI 264453' sorghum was found to be highly resistant, 'Post' and 'Will' barley, and 'Amigo' wheat were moderately resistant, and 'Wintermalt' barley, 'Largo', 'DS 28-A', and 'Tam W-101' wheats were highly susceptible. Oats 'CI 4888' was moderately resistant (damage rating 5), oats 'CI 1579' and oats 'CI 1580' were resistant (damage rating 3). The local susceptible checks ('Tandojam-83, 'WL-711', and 'Faisalabad-83') were found susceptible. Thus it seems that this population behaves some what similar to biotype B but not exactly like this. Therefore, it is designated as biotype *PK-1*.

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Resistance in Recommended wheat Cultivars

According to variable climatic conditions and cropping pattern, Pakistan has been divided into various wheat zones, and various cultivars are recommended in each zone. At present about 44 wheat cultivars are grown in various climatic zones of the country. These wheat cultivars were tested in the laboratory for resistance against greenbug.

Firstly a seedling bulk test was conducted to determine the overall resistance in each entry, and then the nature of resistance was determined in selected entries by conducting antixenosis, antibiosis and tolerance tests. In the seedling bulk test, 'Punjab-85' was found to be resistant with a damage rating of 3. 'Faisalabad-85' was moderately resistant with a damage rating of 4. 'PARI-73', 'Sandal' and 'Yecora' had a damage rating of 5 and 'PAK-81', 'WL-711', 'Sutluj-86' and 'Nuri-70' had damage rating of 6 indicating intermediate level of resistance in these cultivars. All the remaining cultivars, namely, 'LU-26', 'BWP-79', 'C-228', 'C-271', 'C-518', 'C-591', 'Chakwal-86', 'Dirk', 'Khyber-79', 'LYP-73', 'Punjab-81', 'SA-75', 'Sarsabaz', 'ARZ', 'Barani-83', 'Blue Silver', 'C-273', 'Chenab-70', 'Chenab-79', 'Faisalabad-83', 'Khyber-87', 'Kohinoor-83', 'Mexipak', 'Pavon', 'Pirsabak-85', 'Potohar', 'Punjab-76', 'Rawal-87', 'Sind-81', 'Sultan-86', 'Tandojam-83', 'Wadanak-85', 'ZA-77', 'Zamindar-80' and 'Zargoon-79' were found highly susceptible to greenbug with a damage rating of 7 to 9.

Some of the wheat cultivars, namely, 'PARI-73', 'WL-711', 'Yecora', 'PAK-81', 'Sind-81', 'Punjab-85', 'Faisalabad-83', 'Faisalabad-85', 'Sandal' and 'Tandojam-83' were tested to determine the nature of resistance in them. Of these 'Punjab-85' was resistant, 'PARI-73', 'WL-711', Yecora', 'PAK-81', 'Faisalabad-85' and 'Sandal' were moderately resistant, and 'Sind-81', 'Faisalabad-83' and 'Tandojam-83' were highly susceptible.

Three separate tests, namely, antixenosis, antibiosis and tolerance were conducted to determine the nature of resistance. All these tests were conducted in the laboratory at 27 ± 2° C, 60% RH and 16:8 hr regime. In each test, there were 10 replications and the design was randomized complete block. Data were analyzed statistically, and the means were separated by using Duncan Multiple Range Test (DMRT).

For antixenosis test, the entries were randomized and planted in a circular pattern about 3 cm from the edge of a 30 cm diameter (14 cm high) plastic pot. There was one plant of each entry in a pot. When the plants were about 5 to 8 cm tall, 50 adult greenbugs were released on the soil in the center of the pot. The plants and greenbugs were

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covered with a plastic cage (29 cm in diameter by 25 cm high). The tops of the cages were covered with muslin cloth. There were also two muslin cloth covered ventilation holes (5 cm diameter) in the sides of the cages. All the pots were placed in a dark room to eliminate the effect of light on the greenbug orientation towards the plants. After 24 hours of the release of greenbugs, all the plants were observed and the number of greenbugs present on each plant were counted.

In this test, 'PARI-73', 'WL-711' and 'Yecora' were found to be the least preferred (mean number of greenbugs 1-2 per plant), whereas 'Faisalabad-83' and 'Tandojam-83' were found to be the most preferred by the greenbug (mean number of greenbugs 7-8 per plant). This confirms the findings of the previous test. There were no significant differences ($P > 0.05$) among the mean number of greenbugs on 'PARI-73', 'WL-711', 'Yecora', 'PAK-81', 'Sind-81', 'Punjab-85' and 'Sandal'.

The antibiosis test measures the fecundity of the test females on the test host. The seed of a selected entry was planted in a standard soil mix in 7 cm diameter (7.5 cm high) pot and thinned to one seedling per pot. Individual plants were infested at the first-leaf stage with three greenbugs from the laboratory colonies. Each plant was then covered with a plastic cage (6 cm diameter by 30 cm high) with a cloth top and cloth-covered ventilation holes on the sides. The cages confined the greenbugs to the proximity of the plant and also prevented contamination from occasional stray greenbugs. The plants and greenbugs were observed daily. When reproduction began, adults were removed, leaving five nymphs on each plant. Nymphs were allowed to grow on the test plant until they matured and began to reproduce. At this time, all aphids but one were removed from the plant. Nymphs were removed from the plant daily, and their numbers were recorded until the adults stopped reproducing about 20 days later. The plants were clipped periodically to facilitate handling.

The lowest number of nymphs (mean 49.0 $\pm$ 9.17 per female) were produced on 'Punjab-85'. However, there were no significant differences ($P > 0.05$) in the mean number of nymphs produced per female on 'Punjab-85', 'WL-711' (58.30), 'Tandojam-83' (59.90), 'PARI-73' (61.30), 'Faisalabad-83' (61.80), 'PAK-81' (67.0) and 'Faisalabad-85' (67.20). The maximum number of nymphs (76.60 $\pm$ 15.02 per female) were produced on 'Yecora'. However, there were no significant ($P > 0.05$) differences in the mean number of nymphs produced per female on 'PAK-81', 'Faisalabad-85', 'Sind-81', 'Sandal' and 'Yecora'. In fact DMRT grouped these means in three overlapping groups. However, it is evident that 'Punjab-85' has high level of antibiosis.

For tolerance test individual seedlings of the test entries were grown as described in the previous section. When the seedlings attained a height of 5 to 6 cm, they were infested with laboratory-reared apterous greenbug females at the rate of 10 greenbugs per seedling. The seedlings and greenbugs were covered with plastic cages as described earlier. One set of plants received no greenbugs. The plants were observed daily, and the greenbugs were counted. The greenbugs were added or removed and a level of 10 greenbugs per plant was maintained. Twelve days later, the infested plants were visually rated for damage by using a scale ranging from 0 (no damage) to 9 (dead or dying plant).

The tolerance test measures the ability of a plant to withstand the attack of a pest. In this test the lowest damage was recorded on 'PARI-73' (mean damage rating 4.10 $\pm$ 2.60), followed by 'Sandal' (4.80 $\pm$ 2.0) and 'Punjab-85' (4.8 $\pm$ 2.0) in ascending order. However, the means were not significantly different ($P > 0.05$). The damage rating on 'PAK-81', 'Tandojam-83', 'Yecora', 'WL-711' and 'Faisalabad-83' varied from 5 to 5.8, however, there was no significant ($P > 0.05$) difference in the means of all these cultivars. 'Sind-81' had a damage rating of 7.3 $\pm$ 1.16 and 'Faisalabad-85' had damage rating of 7.4 $\pm$ 1.26, and the means were not significantly different ($P > 0.05$). In this test also, DMRT grouped the mean damage ratings on all these cultivars in three overlapping groups.

These three tests, namely, antixenosis, antibiosis and tolerance, indicate that resistance in 'Punjab-85' is mainly due to antibiosis and a low level of tolerance.

Resistance in Wheat Germplasm

Some 481 germplasm lines procured from the Plant Genetic Resources Program, National Agricultural Research Centre, Islamabad, were tested in the laboratory for resistance against greenbug. Of these 42 germplasm lines failed to germinate.

Sixteen germplasm lines were found to have high level of resistance against greenbug. The damage rating on these lines varied from 2 to 3 (0, healthy; 9, dead). These lines were 'PAK 15081', 'PAK 15115', 'PAK 15139', 'PAK 15242', 'PAK 15433', 'PAK 15479', 'PAK 15481', 'PAK 15519', 'PAK 15992', 'PAK 15994', 'PAK 15995', 'PAK 15997', 'PAK 16007', 'PAK 16008', 'PAK 16010' and 'PAK 16190'. These entries were re-tested and were again found to be highly resistant.

Of the tested entries 114 were moderately resistant with damage rating 4 to 6 at 0 to 9 damage scale. Of these 29 entries ('PAK 15082', 'PAK 15091', 'PAK 15340', 'PAK 15396', 'PAK 15429', 'PAK 15436', 'PAK 15458', 'PAK 15485', 'PAK 15531', 'PAK 15532', 'PAK 15535', 'PAK 15547', 'PAK

15591', 'PAK 15593', 'PAK 15594', 'PAK 15605', 'PAK 15635', 'PAK 15637', 'PAK 15643', 'PAK 16006', 'PAK 16012', 'PAK 16048', 'PAK 16049', 'PAK 16052', 'PAK 16060', 'PAK 16061', 'PAK 16074', 'PAK 16179', 'PAK 16323') had a damage rating of four, 33 had a damage rating of 5 and 52 had damage rating of 6.

Of the tested entries, 309 were found highly susceptible to greenbug with damage rating of 7 to 9. Of these 78 entries had damage rating of seven, 108 entries had damage rating of eight, and 123 entries had a damage rating of 9 at 0 (healthy) to 9 (dead) damage scale.