Resistance of *Triticum* Species to Cereal Aphids

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Abstract: The resistance of *Triticum* ssp. to English grain aphid (*Sitobion avenae* F.) and bird cherry-oat aphid (*Rhopalosiphum padi* L.) has been studied in different regions of Russia and the former Soviet Union. The dependence of resistance to aphids on the wheat genome constitution was determined. Diploid species with genomes A^u (*Triticum urartu*) and A^b (*T. boeoticum*, *T. monococcum*) are the most resistant. Possessing a D genome in the species *T. kiharae* and *T. miguschovae* gives high resistance. Resistance controlled by the G genome is overcome by the pests.

Keywords: plant resistance; *Rhopalosiphum padi*; *Sitobion avenae*; wheat

An intensification of agriculture has resulted in a considerable increase in aphid damage to cereal crops. The genetic uniformity of cultivars disturbs population homoeostasis and promotes adaptive microevolution in pests. The use of broad spectrum pesticides also leads to a disturbed biological balance: the death of aphidophages and the mass reproduction of pests are observed. In addition, resistance to insecticides was noted in aphids. Breeding resistant plants is the most effective and, at the same time, the cheapest and most ecologically sounds method of protection from aphids. As a result of losses, the benefits of breeding for plant resistance grow faster than the cost.

In Russia, the bird cherry-oat aphid (*Rhopalosiphum padi* L.) and English grain aphid (*Sitobion avenae* F.) are the aphid species most abundant on wheat. Yield losses result from the aphids feeding, and from aphids serving as vectors for virus diseases. With the objective of preventing insect outbreaks, resistant varieties with different genetic sources are to be developed. Effective resistance has not been found in bread wheat, and the use of cereal aphid resistant wild *Triticum* germplasm in interspecific crosses with cultivated varieties may be a method of minimizing damage to wheat. The essential advantage of resistance gene introgression is the assurance that the sources of these genes have not been exploited previously in breeding. This paper presents the results of field evaluations of wild wheat accessions from the Gene Bank of N.I. Vavilov All-Russian Research Institute of Plant Industry (VIR).

MATERIALS AND METHODS

The field resistance of 1043 accessions representing 30 wild *Triticum* species (Dorofeev *et al.* 1979) to *S. avenae* has been studied at the Northern Caucasus (Dagestan Experimental Station of VIR – DES VIR), and in Uzbekistan (Uzbek Institute of Grain – UIG and Uzbek Institute of Plant Industry – UIPI). An outbreak of *R. padi* in fields at the Pushkin Filial of VIR (PF VIR) in St. Petersburg in 1990 promoted the assessment of the abundance of the pest on 93 accessions of *T. monococcum* and 470 accessions of *T. dicoccum*, i.e. most of these species collections, and also some other wheat species. The experiments were conducted in the periods 1983–1997 and 2008–2009.

The number of aphids on a plot was estimated by examination of a shoot sample in the field. Infestation was rated by using a scale ranging from 0 (no aphids) to 5. A resistance rating of wheat accessions was carried out when the aphid abundance on susceptible control varieties corresponded to a score not less than 3. An infestation score of a particular accession was estimated according to the ultimate aphid abundance on the plants.

RESULTS AND DISCUSSION

Considerable variability among wild polyploid species for resistance to *S. avenae* was revealed. These data can be summarized as follows:

Subgenus *Triticum.* Section *Urartu* Dorof. et A. Filat (genome A^u) includes highly resistant types, the ultimate abundance of *S. avenae* on *T. urartu* ears corresponds to an infestation score of 2 (Table 1).

Ten species within the *Dicoccoides* Flaksb. section (genome A^uB) could be classified as intermediately resistant to susceptible for the feeding of English grain aphid. Within *T. dicoccoides* and *T. dicoccum*, however, considerable variation existed for aphid infestation levels. Infestation scores ranged from 1 to 5. European (subsp. *dicoccum*) and Moroccan (subsp. *maroccanum*) emmers are susceptible to the aphid. Within Eastern (subsp. *asiaticum*) and Ethiopian (subsp. *abyssinicum*) emmer collections there are quite resistant accessions: k-13635, k-13483, k-43872 (Armenia), k-6391 (Azerbaijan), k-14380 (Turkey), k-19622 (Ethiopia) and others. Infestation rates of *T. karamyschevii* ears in Uzbekistan had scores of 4–5, in Dagestan it had a score of 2.

Naked-grained tetraploids are less resistant to the pest as compared to glumaceous species. *T. turgidum*, *T. jakubzineri*, *T. turanicum* and *T. polonicum* were heavily infested. The English grain aphid did not heavily infest (scores of 2–3) *T. ispahanicum* in Dagestan, but under Uzbekistan conditions this species was susceptible. *T. aethiopicum* was susceptible to *S. avenae* and the infestation rating of ears (mainly scores of 3–4) was independent of general aphid abundance on the wheat collection. *T. persicum* is close to *T. aethiopicum* for resistance behavior. It can be noted that only the accession k-6428 (Georgia) was relatively weakly infested in the study.

The overall level of aphid resistance in the hexaploid *Triticum* section (genomes A^uBD) was similar to that of *Dicoccoides*. *T. spelta* was the most susceptible among the six species evaluated. Some accessions of *T. vavilovii*, *T. compactum* and *T. sphaerococcum* were highly resistant to the English grain aphid. The damage score on *T. vavilovii* varied from 2 (DES VIR) to 5 (UIPI). This is probably due to the fact that despite a very rough ear this wheat species possesses some level of resistance that is overcome during heavy outbreaks of the insect. *T. compactum* was also relatively susceptible to the pest; especially when there was a high density of the aphid on plants in UIPI. The accession k-52640 (Uzbekistan) was noted as having quite a high level of resistance (infestation score of 2) both in UIG and DES VIR. Aphid density on accessions of *T. sphaerococcum* in our trials was moderate (primarily scores of 3). It must be noted that the accessions k-5499 (India) and k-46453 (Pakistan) were relatively resistant in Uzbekistan and Dagestan. *T. petropavlovskyi* was resistant to the pest under conditions of restricted aphid infestation, but did not express resistance under a high aphid population. Thus, in UIG, the infestation scores in different years varied from 2 to 5.

Subgenus *Boeoticum* Migusch. et Dorof. Wheat species within the *Monococcum* Dum. section (genome A^b) are the most resistant to English grain aphid. The infestation rating of *T. boeoticum* in most cases did not exceed 1. The pest was not found over a number of years, in the two regions of the study, on the accession k-28239 (Azerbaijan). All *T. monococcum* accessions were resistant to *S. avenae*. In Dagestan, considerable variation was observed (Table 1). The most serious infestation was observed on the accessions belonging to West-European mountain and Mediterranean groups: k-40063, k-41931, k-46746 (Germany), k-20498 and k-21038 (Italy). The naked-grained diploid species *T. sinskajae* originated as a result of a spontaneous mutation within plants of *T. monococcum* (k-20970) from Turkey, and this was less resistant to the aphid. The infestation rating of the accession k-20970 in UIG and DES VIR was 1, and *T. sinskajae* 2 and 3, respectively.

Section *Timopheevii* A. Filat. et Dorof. (genomes A^bG, A^bA^bG, A^bA^bGG, A^uA^bBG) consists of wheat species that are primarily low or moderately infested by the aphid. For *T. araraticum*, large variation of aphid density on the ears was a characteristic, especially under Dagestan conditions. *T. araraticum* subsp. *kurdistanicum* was more resistant than subsp. *araraticum*. *T. araraticum* was relatively resistant to the pest in UIG, also at a very high aphid density in the field. Some level of field resistance to the aphids was shown by *T. timopheevii*, but at very high aphid density this species failed to retain the resistance. One explanation for this loss of resistance could be that natural aphid populations appear to be genetically highly polymorphic and contain host-virulent biotypes that overcome the resistance, and which accumulate during the vegetative period.

Table 1. Resistance of different wheat species to English grain aphid

Subgenus	Section	Genome	No. of accessions tested	Percentage of accessions in each category of resistance					
				0	1	2	3	4	5
Dagestan Experimental Station of VIR									
	Urartu	A^u	10	–	90.0	10.0	–	–	–
Triticum	*Dicoccoides*	A^uB	555	–	3.4	15.3	51.2	25.0	5.1
	Triticum	A^uBD	185	–	1.1	21.1	56.8	14.6	6.4
	Monococcum	A^b	98	15.3	71.4	7.2	5.1	1.0	–
	Timopheevii	A^bG	44	4.3	20.5	36.4	34.1	4.5	–
	Timopheevii	A^bA^bG	1	–	–	–	–	100.0	–
Boeoticum	*Timopheevii*	A^bA^bGG	1	–	–	–	100.0	–	–
	Timopheevii	A^uA^bBG	3	–	–	66.7	–	33.3	–
	Kiharae	A^bGD	2	–	100.0	–	–	–	–
Total			899	1.9	12.4	16.7	45.6	19.0	4.4
Uzbek Institute of Grain									
	Urartu	A^u	3	–	100.0	–	–	–	–
Triticum	*Dicoccoides*	A^uB	212	–	0.5	9.0	37.7	43.4	9.4
	Triticum	A^uBD	93	–	–	3.2	32.3	40.9	23.6
	Monococcum	A^b	56	3.6	94.6	1.8	–	–	–
	Timopheevii	A^bG	27	–	11.1	29.6	59.3	–	–
	Timopheevii	A^bA^bG	1	–	–	100.0	–	–	–
Boeoticum	*Timopheevii*	A^bA^bGG	1	–	–	100.0	–	–	–
	Timopheevii	A^uA^bBG	2	–	–	50.0	50.0	–	–
	Kiharae	A^bGD	2	–	–	100.0	–	–	–
Total			397	0.5	15.1	9.1	32.0	32.7	10.6
Uzbek Institute of Plant Industry									
	Urartu	A^u	4	–	50.0	50.0	–	–	–
Triticum	*Dicoccoides*	A^uB	266	–	–	0.7	42.5	42.5	14.3
	Triticum	A^uBD	56	–	–	1.8	26.8	50.0	21.4
	Monococcum	A^b	16	–	56.2	43.8	–	–	–
	Timopheevii	A^bG	9	–	11.1	11.1	33.4	22.2	22.2
	Timopheevii	A^bA^bG	1	–	–	100.0	–	–	–
Boeoticum	*Timopheevii*	A^bA^bGG	1	–	–	–	100.0	–	–
	Timopheevii	A^uA^bBG	1	–	–	–	–	100.0	–
	Kiharae	A^bGD	1	–	–	100.0	–	–	–
Total			355	–	3.4	4.2	37.2	40.6	14.6

Naked-grained tetraploid *T. militinae* originated from spontaneous mutation of *T. timopheevii* and was moderately infested by the aphid. Under the conditions of the northern Caucasus, the species *T. zhukovskyi* almost completely lost resistance to the pest. At the same time, this species is highly resistant to the Uzbek and northwestern populations of English grain aphid. *T. flaksbergeri* (an allo-octoploid species developed as a result of hybridization between *T. militinae* and *T. persicum*), and *T. timonovum* (autooctoploid of *T. timopheevii*) were moderately infested by the pest. The allo-octoploid species *T. fungicidum,* developed from crossing *T. timopheevii* and *T. persicum* is relatively susceptible to *S. avenae*.

Thus, the resistance of species from the *Timopheevii* section might be overcome by cereal aphids. We found different interactions of *S. avenae* with *T. zhukovskyi*, not only in the field but also in laboratory experiments (Radchenko 1987). Earlier, the biotype KS-5 of *Rhopalosiphum maidis* Fitch. was found which overcomes the resistance of *T. timopheevii* (Wilde & Feese 1973).

Section *Kiharae* Dorof. et Migusch. (genome A^bGD) consists of two hexaploid wheat species resistant to English grain aphid. One is *T. kiharae* (developed from crossing *T. timopheevii* × *Aegi-lops tauschii*), and the second, *T. miguschovae*, originated from a spontaneous mutant of the amphiploid *T. militinae* × *Ae. tauschii*. Obviously, aphid resistance appears to be determined by the D genome from *Ae. tauschii*. The infestation rating of this species of goat grass in Dagestan did not exceed a score of 2.

The analysis of a polyploid series of wheats demonstrates the large variability in the frequency of genotypes resistant to English grain aphid. A relationship between aphid resistance and different wheat genomes was detected. The diploid species with the genomes A^u (*T. urartu*) and A^b (*T. boeoticum*, *T. monococcum*) are the most resistant to *S. avenae*. Species from the section *Timopheevii* have some resistance but this can be overcome by the aphid. The D genome from *Ae. tauschii* provides high levels of resistance to *S. avenae* in *T. kiharae* and *T. miguschovae*.

We observed a very heavy bird cherry-oat aphid outbreak in the field of PF VIR. The prevalent infestation rating was 3 for *T. monococcum* accessions and 4 for *T. dicoccum* accessions, but sixteen accessions of *T. monococcum* were infested less (infestation rating of 2). Among *T. dicoccum* accessions, no genotypes with an infestation rating of 2 were found, and 18 accessions (primary from Armenia) were slightly less populated by aphids. In our experiments, the heavy infestation on some accessions by *R. padi* does not match with their high resistance to *S. avenae* in Dagestan and Uzbekistan; in other words, different genes determine resistance to these two different aphids. At the same time, *T. kiharae*, *T. miguschovae*, and some *T. monococcum* accessions were found to be resistant to both aphid species. Multiple evaluations of collections of wild wheat are very important because these give breeders a better chance of selecting appropriate lines with multiple resistances to harmful organisms. For instance, some accessions of *T. monococcum* combine aphid resistance with resistance to rusts and powdery mildew.

Different interactions with the host genotype are specific to the grain aphids. The existence of aphid biotypes with different levels of host-virulence makes it necessary to identify new resistance genes for breeding programs. It is to be expected that genetic diversity for resistance to aphids can provide protection against the selection of virulent insect biotypes. The low levels resistance of soft and hard wheats makes the work on introgression of genes for resistance especially useful.

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