Both susceptible (left) and resistant oat plants are infected with BYD, even though only the susceptible variety shows symptoms. Corn (right) has been implicated as an important source of BYD virus in some areas of the United States.

Barley yellow dwarf of California cereals

John A. Griesbach ❑ Rebecca Creamer ❑ Gale Lorens
Bryce W. Falk ❑ Calvin O. Qualset ❑ Lee F. Jackson

Research on barley yellow dwarf disease in California small grains is designed to develop cultural controls and cultivars with improved resistance. Recent discovery of BYDV satellite RNA that inhibits replication of the virus offers additional hope of control.

Much has been learned about barley yellow dwarf since it was discovered in 1951 that aphid-transmitted viruses (BYDVs) caused the disease. Despite its rating as the most economically important viral disease of small grains in the world, however, information on how to deal with BYD is still limited.

BYD affects all small grains, many pasture grasses and grassy weeds, corn, and rice. Although California hasn't had a major epidemic of the disease in many years, local epidemics are commonplace in many parts of the world. In the United States losses to BYD are estimated at 1% to 3% annually, but up to 40% damage has been reported in isolated cases. Mild, wet winter weather followed by a dry spring can lead to a population explosion of aphid vectors that infest grain fields when the plants are young and most vulnerable.

Symptoms of infection generally include reddening of oat and yellowing of barley and wheat leaves, stunting of plants, and reduced yields. The symptoms often aren't distinct, however, and they can be confused with nutrient deficiencies or other conditions. Infection by more than one type of barley yellow dwarf virus can increase disease severity and crop losses.

BYDVs are transmitted by a variety of cereal aphids, which acquire the virus by feeding on infected plants. Primary infection (field-to-field or long-distance spread) is initiated by migrating winged aphids in the late fall or spring. Secondary infections (within-field spread) are initiated by winged or nonwinged aphids moving virus from initial infection points. Once an aphid acquires BYDV, it becomes a carrier for life.

Detection and diagnosis

We use three methods to identify specific BYDVs in California: aphid transmission, serology, and nucleic acid hybridization. The first, allowing aphids to acquire the virus by feeding on infected plants and transferring them to healthy plants, is time-consuming and requires large aphid-free greenhouses and aphid rearing facilities. Specific diagnosis of a given BYDV may take several months and repeated transfers. However, aphid transmission assays are essential because they identify which aphid species actively transmits a given BYDV.

The most common assay method is a serological technique called ELISA (enzyme-linked immunosorbent assay). With ELISA, the specific type of BYDV can be identified in two days. This method works well in detecting BYDVs in most plant species, and is used when large numbers of samples are to be screened for BYDV types.

The newest method for BYDV identification involves cloned recombinant cDNA probes. cDNA probe analysis of plant extracts is fast and can be used to process large numbers of samples, but the technique is complex and expensive.

We have used a recombinant DNA probe to measure responses of various wheat cultivars to infection by PAV types of the virus. The probe (pPA8, developed in Australia) is specific for PAV. Developing and using recombinant DNA probes may prove helpful in screening cultivars for resistance, since they directly measure viral replication.

Distribution in California

A primary objective of our work has been to learn more about the seasonal, geographical, and host incidence of different BYDVs in California. Analysis of 561 samples of cereal grains from 16 locations in 1987 showed that BYDVs occur throughout the state, but that the major growing regions vary in the relative frequency of BYDV types (table 1). PAV, the predominant type in California, ranged in 1987 from a high of 90.5% of BYDV in the Imperial Valley to a low of 49.0% in coastal regions. MAVs were most common in the San Joaquin and coastal regions, and lowest in the Imperial Valley. RPVs were the least common type in all growing regions, and were not detected in the Imperial Valley. The highest levels of RPVs were found in the coastal region and Sacramento Valley.

Mixed infections of two and three BYDV types occurred infrequently except in the

San Joaquin Valley (table 1). Five of six locations sampled there had higher than expected levels of MAV-PAV dual infections. Of the 135 samples taken, 49 were ELISA-positive for this combination. A 1988 survey will give us a second year of data to see if dual infections are a regular phenomenon in the San Joaquin Valley.

Most research indicates that cross-protection does not occur in dual infections; rather, they have an additive or synergistic effect on severity of the disease. We are testing these California types individually and together for yield losses in the main cereal cultivars grown in the San Joaquin Valley. If a unique BYD problem exists in this area, a management plan based on statewide averages may not be the best strategy to control this BYD damage.

We have detected BYDV in about 25% of 378 samples of wild oats, native grasses, permanent pasture, and corn collected throughout the state. The data are from ELISA tests; aphid transmission tests have not been completed. It seems, however, that BYDVs can survive in wild and native grasses and other alternate hosts while small grains are temporarily absent.

Control

BYD is controlled by three main methods: restricting the planting date, using resistant crop plants, and applying insecticides to control aphids.

Restricting the planting date ensures that plants are not in the susceptible seedling stage during peak aphid flights. The age of the plant at infection is a critical factor in crop losses. Yield loss is about twice as great if plants are infected at the seedling stage rather than the tillering stage. Similarly, plants infected at the tillering stage will suffer about twice the loss of those infected at stem extension and pre-boot.

The recommended planting time of November to December for most of California allows the grain to be in a fairly advanced state when aphid populations and flights peak in March and April. However, growers can be forced into late planting dates by unfavorable weather or other factors, which will increase the risk of exposure to BYD. Increased vulnerability could also result from earlier planting (September-October), which may be necessary with winter wheats that require vernalization. Such seedlings may be exposed to aphids and BYD in the fall before the onset of cooler temperatures.

The most effective way to control BYD is through host plant resistance (HPR). A single gene for BYD resistance in barley (Yd_2), has proved effective in reducing losses to the most common BYDV type (PAV). Most barley cultivars carry the Yd_2 gene. A single gene with the same degree of resistance hasn't been identified in either oats or wheat, even though much of the world collection has been screened. Resistance in oats and wheat appears to be quantitative and controlled by many genes. Resistant oat cultivars were developed using several sources of HPR. Highly resistant wheat, however, has not been found even from several thousand cultivars in the world collection. Several with limited resistance, such as Anza, are being intercrossed to select for highly resistant types.

The UC Davis program to increase resistance is multifaceted. The U.S. Department of Agriculture supports a joint program in which all entries from the world collection of barley, oats, and wheat are being screened at Davis for resistance to BYDV. Cooperative exchange of material with researchers throughout the United States and many parts of the world allows access to many sources of resistance. A novel approach at Davis to improve resistance in wheat is the transfer of the barley chromosome containing the Yd_2 gene.

The third BYD control strategy, the use of insecticides to control aphids, is usually not economically practical and has not been tested adequately in California. Pyrethroids are used in Europe on spring-sown grains to control virus-carrying aphids. While insecticides won't eradicate aphids, they will suppress secondary spread and in effect delay infection, thereby limiting crop losses.

TABLE 1. Barley yellow dwarf virus occurrence in barley, wheat, and oats in California's major growing regions, 1987

BYDV isolate*	No. of samples (N)·	BYDV/ N§	Isolate % by region¶
Northern region (77,966 acres)	64	0.36	
PAV			69.0
MAV			24.0
RPV			7.0
Sacramento Valley (306,679 acres)	265	0.40	
PAV			61.0
MAV			21.9
RPV			17.1
San Joaquin Valley (415,530 acres)	135	1.13	
PAV			58.2
MAV			34.4
RPV			7.4
Coastal Region (159,625 acres)	101	0.51	
PAV			49.0
MAV			33.3
RPV			17.7
Southern Region (144,714 acres)	69	0.30	
PAV			90.5
MAV			9.5
RPV			0.0

* Of five distinct BYDVs found in U.S., the three tested and their vectors were: PAV, rose grass aphid (*Metopolophium dirhodum*), oat-bird cherry aphid (*Rhopalosiphum padi*), and others; MAV, English grain aphid (*Sitobion avenae*); RPV, *R. padi*. The two other BYDVs and their respective vectors are: RMV, corn leaf aphid (*R. maidis*) and SGV, greenbug (*Schizaphis graminum*). Eighteen other aphid species have also been described as BYDV vectors.

· Samples taken in 1987, except northern region samples, which are from 1986.

§ Frequency of BYDV isolates per symptomatic sample. Value greater than 1.00 indicates mixed infections of two or more isolates are common.

¶ Occurrence in each region, calculated as a percentage of total BYDVs per region.

Aphids are being monitored in a coordinated project in the western United States and in England to determine when cereal aphid vectors migrate. Monitoring data from Washington state during the fall and winter of 1982-83 showed that 3.4% to 14.5% of the aphids trapped transmitted BYDV, and that oat-bird cherry aphid was the most important vector. This information can be used to adjust planting dates or schedule insecticide sprays.

An aphid monitoring station was recently placed on the UC Davis campus. Aphids are collected weekly and identified by species. In a parallel study, weekly field plantings of trap plants (oats) are synchronized with aphid collection to detect the onset and duration of fights of BYDV-viruliferous aphids and to identify the specific types they transmit. The correlation between disease onset and a particular vector could be valuable in management decisions.

Future research

From our research we hope to gain a detailed understanding of BYD in California cereals. The goal is to develop more effective ways of controlling BYD by cultural methods as well as through the use of cereal cultivars with improved resistance to BYDV types.

The discovery by Australian plant virologists of BYDV satellite RNA (a biological agent smaller than the BYDV virus particle that is parasitic on the RPV type) is a positive development. Satellites are fairly common among plant viruses, but whether or not they offer a realistic means of virus suppression is just being investigated. The procedure involves the insertion of the satellite genetic sequence into a susceptible cultivar. When the cultivar becomes infected with BYDV, the BYDV replication is inhibited by the satellite RNA and thus is controlled. This protection, if realized, has the potential to by-pass the control of aphid vectors and the restrictions of planting dates to avoid aphids.

John A. Griesbach is Post-Graduate researcher, and Rebecca Creamer is Graduate student, Department of Plant Pathology, University of California, Davis; Gale Lorens is Post-Doctoral Associate, U.S.Department of Agriculture Agricultural Research Service, Albany, California; Bryce W. Falk is Associate Professor, Department of Plant Pathology, UC Davis; Calvin O. Qualset is Professor, and Lee F. Jackson is Extension Agronomist, Department of Agronomy and Range Science, UC Davis.