Utilizing genetic diversity

Charles W. Schaller

The late C.A. Suneson of U.C. Davis was a world leader in barley breeding.

Considerable effort has been made over the years to systematically collect, preserve, and identify the germplasm resources of barley on a worldwide basis. One of the largest collections of barley germplasm has been assembled and maintained by the United States Department of Agriculture at Beltsville, Maryland. This collection, numbering approximately 20,000 entries, is available to scientists throughout the world and has been utilized extensively in the continuing improvement and protection of barley cultivars for California. Researchers at the University of California at Davis have not only utilized this collection in their breeding programs but have contributed substantially to the identification of important sources of germplasm for specific plant characteristics, primarily in the area of disease resistance.

Introduced by Spaniards

Barley has been successfully grown in California since the days of the early Spanish settlers. One previously important cultivar, 'Atlas', of which improved strains are still being grown, was a pure line selection from the cultivar 'Coast', which in turn was of North African origin and was apparently introduced here by the early Spanish before 1771. Subsequent introductions, including two of major importance from Egypt, Club Mariout and California Mariout, established barley as an important crop in California. California Mariout, introduced in 1905 and released to growers in 1912, was the leading variety in California for 60 years until replaced in 1972 by CM 67, a disease-resistant, white seeded successor.

Although well adapted to environmental conditions in California, these early introductions and reselections were susceptible to several major diseases, each capable of severely reducing yield and quality. In most cases, resistant cultivars offer the only means of effective economical control because other methods, such as chemical treatment, are not practical.

Disease resistance

Drawing on the reservoir of germplasm in the world collection of barleys, sources of resistance to these diseases were identified, both on a varietal and genetic basis, and are being utilized. Seven genes for resistance to powdery mildew have been identified at Davis in introductions from such widely diverse areas as China, Algeria, Russia, and India. Two of these genes have been used in our breeding programs. The gene in the Algerian selection is particularly noteworthy in protecting against all races of powdery mildew occurring in California and, until recently, to all races present in the United States and Canada. Detailed studies have shown that mildew reduces yield by about 10 percent statewide, but up to 25 percent in some areas if resistant varieties now available are not used.

Although 10 genes conditioning resistance to *Rhynchosporium* scald have been identified at Davis (as well as a number of different genes by other workers), none of them protect against the complexity of races occurring in California. Thus, the search goes on. Under the leadership of R.K. Webster, Department of Plant Pathology at Davis, the entire 20,000-entry U.S.D.A. world collection is being screened for scald reaction from which to develop resistant cultivars. Barley scald losses equal or can exceed those of powdery mildew.

A third disease, net blotch, is important in many areas of the state. When a breeding program for resistance was initiated at Davis in 1948, no suitable sources of resistance were available. Screening of the world collection, then numbering about 4,500 entries, showed only 75 entries with some resistance. Subsequently, 3 genes were identified and are being used in the breeding program. Interestingly, nearly all of the 75 resistant entries originated in Manchuria, a country represented by only 12 percent of the world collection.

Fighting new diseases

The significance of access to a worldwide germplasm reservoir was further illustrated by the outbreak and subsequent control of the devastating disease, barley yellow dwarf. This previously undescribed and unrecognized disease occurred in widely infectious proportions in California in 1951. It was identified at Davis as an aphid-transmitted virus disease, capable of infecting not only barley, but wheat, oats, and a number of other grass species. Since then it has been found in nearly all important cereal growing areas of the world, and in many of

in the improvement of barley cultivars

them is of major importance. Locally and statewide, widespread attacks have occurred every year since 1951. Barley yellow dwarf is now the major disease of barley in California and resistant cultivars offer the only means of control.

In 1951, all of the commercial cultivars nationwide were susceptible to barley yellow dwarf. In the immediate search for resistance the entire world collection was screened and 117 entries were found to possess sufficient resistance to utilize in a breeding program. Except for one from China, all were introductions from Ethiopia. This is in sharp contrast to the findings with net blotch, where the majority of the resistant types were from Manchuria, and for mildew, where the resistant types had come from many areas.

Subsequent genetic studies at Davis on barley yellow dwarf, involving 30 or more of the resistant types, identified only one major gene conditioning resistance, which is being used in breeding programs throughout the world. However, use of this single gene worldwide has led to considerable concern regarding the vulnerability of the derived cultivars to a possible shift in virulence of the virus. Such an occurrence could negate all the breeding efforts and again expose the crop to the ravages of the disease.

Losses versus values

The development and release of yellow-dwarf resistant cultivars showed us more clearly how damaging the disease can be, and yield losses far exceeded the early estimates. For example, 'CM 67' (CM = California Mariout) was released in California in 1968, with the first commercial seed produced in 1970. Since CM 67, which was derived through a backcrossing program, is essentially a white-seeded, yellow-dwarf-resistant strain of the original California Mariout cultivar, the two cultivars would be expected to perform similarly in the absence of the disease. The new variety was compared with California Mariout over a 3-year period (1967 to 1969) at seven locations. *CM 67 yields were better by 6 to 38 percent, with an average of 19 percent,* and individual differences exceeded 30 percent in 4 of the 19 tests!

These yield increases are even more striking in view of California farmers' rapid adoption of CM 67 and successive lines. Within three years of seed availability CM 67 was the major barley planted, and by 1976 yellow-dwarf-resistant cultivars made up about 55 percent of the 1.01 million acre crop. The added productivity is estimated—from the disease resistance alone—at $15 million in crop value; or in terms of feed grains, added supplies sufficient to maintain 100,000 animal units at relatively no additional cost to the grower or consuming public.

Still an 'Atlas'

Finally, the importance of the germplasm availability to the continuous improvement of a crop species is illustrated by the transition of California's original Atlas cultivar. Although well adapted here, it was susceptible to important diseases. Since 1946 several improved strains of Atlas have been developed by University and U.S.D.A. personnel at Davis and are grown commercially. Improved disease resistance and also modifications of morphological characteristics are now combined in Atlas 74. These improvements, together with the seven countries from which donor parents were obtained, are shown in the table.

Cumulative Improvements of the Atlas Cultivar

Strain	Character	Origin of donor parent
Atlas	pureline selection	North Africa, via Spain
Atlas 46	resistance to powdery mildew	Austria
"	" scald	Turkey
Atlas 54	smooth awn	Russia
Atlas 57	white aleurone color	Austria
Atlas 68	resistance to yellow dwarf	Ethiopia
	2nd gene for mildew resistance	Algeria
Atlas 74	resistance to net blotch	Manchuria

Charles W. Schaller is Professor, Department of Agronomy and Range Science, and Agronomist in the Experiment Station, University of California, Davis.