Genetic resources

Genetic diversity is basic to the continued improvement of crop plants, whether through natural selection or directed plant breeding. Although man can use induced mutations to increase diversity, the most important sources of diversity are gene pools that evolve by spontaneous mutation, recombination, and natural selection. Gene pools are preserved in seeds, vegetative parts, and tissue cultures; in the future, we may be able to preserve "DNA clones" as well as additional stocks of cell and tissue cultures. Living plants also represent useful germplasm collections.

The following terms are used in discussing genetic resources:

Primitive cultivars or land races—Crop varieties used in agriculture before the era of modern plant breeding, reflecting a local name, morphological identity, diversity, or adaptability, or perhaps representing local preference for taste, color, or appearance.

Advanced cultivars—Modern varieties developed by plant breeders; also, their pedigrees or related breeding materials.

Induced mutations and genetic stocks—New genetic materials from breeding or experimental genetic studies.

Weedy relatives—Weeds related closely enough to crops to allow continued gene exchange, generating evolutionarily dynamic gene pools.

Crop/weed complexes—Associations of crops with weedy relatives from adjoining wastelands and fields. The weeds are genetically close to the crop, and evolve with it, showing similar responses to herbicides or cultural practices. The weeds may eventually replace the crop in an agricultural field, unless man intervenes.

Wild relatives—Plant species with a botanical relationship to crop plants. They are not as closely related to crops as are weedy relatives. Wild relatives often carry useful genes for vigor, adaptation to stress, resistance to disease and pests, as well as for many unusual biochemical characteristics.

Amaranth seed spikes 2½ feet in length yield upwards of ½ pound of edible grain.

Breeders believe that returning safflower to the original spined-leaf types (left) from the evolved spineless types (right) might provide some natural pest resistance.

Research in sunflowers is being conducted at U.C. Davis by (from left) John Klisiewicz, Benjamin Beard (both USDA), and Paul Knowles (Department of Agronomy and Range Science).

U.C. Davis pepper germplasm stocks produce fruit as small as the ¼ inch wild variety from Colombia, and as large as the domestic 6-inch long red chili.

Bursting cotton bolls signal that harvest is near.

Safflower comes in a variety of flower head colors, shapes, and sizes, and has many uses.

'C2', a prospective strawberry cultivar three backcross generations removed from *F. chiloensis.*

Flax flowers, the source of a valuable oil-seed crop.

Cotton harvesters reap a California bounty enhanced by plant breeding.

U.C. environmental horticulturists have brought longer life, larger size, and striking beauty to the gerbera, or Transvaal daisy, through germplasm selection.

I. COLLECTION & SCREENING

Plant explorers collect plant and seed materials around the world. Large contributions have been made to our collections by individuals, institutions of research and practical breeding, and national organizations, in addition to the contributions of University of California scientists and U.S. Department of Agriculture researchers. Large collections of plant materials are routinely screened for characters useful to plant breeders.

Amaranth and meadowfoam: two new crops?

Holly Hauptli ■ Subodh Jain

Interest in potentially new crops is currently high—news of plant sources for such items as processed food protein, rubber, fuel, and pulp appears almost daily. Whereas 25 or 30 major crop plants meet our needs for food, fiber, or shelter, even a partial list of known useful plants cultivated by man in the past, would run over 20 to 30 thousand names.

Amaranth, an ancient crop in many tropical areas of the world, has not been grown extensively in North America. In contrast, the crop potential of meadowfoam was recognized only recently, as the supply of sperm-whale oil diminished. Some amaranths and a majority of meadowfoam species are native to the United States, and present a great diversity of genetic resources for breeding.

Grain amaranths

The genus *Amaranthus* (Amaranthaceae) contains four ancient crop species: *Amaranthus hypochondriacus*, *A. caudatus*, *A. cruentus*, and *A. edulis*. They originated in Central and South America and were domesticated earlier than, or concurrently with, corn. Since early colonial days, amaranths made their way from Mexico, Guatemala, and the Peruvian Andes to India, Africa, Europe, and Asia. Amaranths are currently grown as a grain crop in northern India, Southeast Asia, and Manchuria. People in tropical West Africa know the grain amaranths better as potherbs; they harvest immature plants and cook the leafy greens.

Although they were probably first domesticated for their red pigment as a dye, both amaranth seed and young vegetation are excellent sources of protein. Seed protein is high (16 to 19 percent) and has a good amino acid complement (biological value of 75 on a scale of 0 to 100). Leaf protein is as high as 33 percent of dry matter, and digestibility is higher than 80 percent (compares well with beef, egg,and *Triticale*).

The crop grows rapidly because of its C_4 carbon-fixation metabolism, and responds luxuriantly to added nitrogen suggesting efficient nitrogen assimilation. The amaranths are summer annuals which may be planted in central California from April 15 to May 1. All species are monoecious, with inconspicuous male and female flowers in a single spike, but breeding system needs to be determined. At Davis, we are exploring the yielding capacity of different species in California, and nutritive values of seed under different nutrient and water regimes. A preliminary trial of *A. caudatus* and *A. hypochondriacus* in 1976 produced seed yields of 1 and 1½ tons per acre, respectively.

Variation in Some Agronomic Traits in Four Domesticated Species of *Amaranthus**

Branching: 1) devoid of branches; 2) branches occur all along stem, but only bear leaves; 3) many tiny flowering branches occur at the base of the inflorescence; 4) larger branches occurring along the stem depending upon light intensity.

Position of inflorescence: 1) erect, spike shading leaves; 2) drooping, spike shaded by leaves—only *A. caudatus* and *A. cruentus*.

Panicle compactness: 1) quite compact, spike branches directly adjacent to one another; 2) lax, spike branches spaced up to 7 to 8 cm apart on main inflorescence stalk.

Seed color: 1) white—all except *A. cruentus*; 2) pink—*A. caudatus* only; 3) many shades of brown; 4) black.

Pigmentation of stem, leaf, and inflorescence: 1) different colors of green, dark and light; 2) a staggering array of red pigmentation expression on different organs, and at different times in the life cycle are available.

Flowering time: 1) day-neutral plants, flowering when they reach a certain size; 2) various photoperiods allowing plants to flower from late July to mid-September in Davis.

*Unless noted otherwise, all four species have the traits listed here.

Large collections of each of the domesticated species will be assembled at Davis for an extensive survey of their variation in morphological and physiological characters. Agronomically important traits such as the spike type and branching pattern, response to photoperiod, and seed size and colors show variation within each of the domesticated species (see table). As efforts to grow this crop will undoubtedly pose new disease and pest problems, resistant genotypes must be discovered and documented.

As has been done with other better known crops, the optimal combinations of yield components, or those morphological or physiological characteristics contributing the most to yield, must be discovered. Any germplasm collection used for breeding would require many native population accessions to ensure that an appropriate maturity date be reached for any particular region.

The U.S.D.A. maintains about 20 collections of grain amaranths, and a few more are privately maintained. In addition, the many localized land races of the crop grown in remote areas of Central America and the Peruvian Andes should be collected and preserved. Many weedy

Meadowfoam, a California wildflower, could possibly become a valuable oil crop. Meadowfoam seeds include: *left,* "Foamore," a cultivated type developed by Oregon State University; *center,* the floating pond variety *rosea; right,* the variety *nivea,* found in coastal pastures. Larger individual seeds measure approximately 4 mm.

and cultivated forms and their hybrid populations,including those of the Delta region in California, are likely to be unique in genetic characteristics. Without conservation of such germplasm, this ancient crop genus may lose its valuable genetic resources.

Weedy amaranths

The advantages of weedy amaranths *(A. retroflexus, A. hybridus,* and *A. powellii),* though not fully determined, may be earliness and increased partitioning of biomass to seed production—at the cost of seed shattering and increased branching. Many instances of hybridization and possibly introgression between weedy and crop populations have occurred. One such hybrid population involving 5 species was reported by Jonathan Sauer of UCLA to exist in the Delta area of central California.

Our own large collections from a dozen localities in this area show that these plants are extremely vigorous, sometimes reaching heights of 11 feet, and bearing inflorescences 2 to 4 feet in length. If not as a crop in their own right, such natural hybrid gene pools may be useful in breeding work, as many attempts to make artificial crosses between domesticated species have failed. Gene exchange with various weedy amaranths has probably enriched the genetic resources of the grain amaranths in ways useful to their development into a new crop for California.

Meadowfoam

The genus of meadowfoam, *Limnanthes,* is endemic to California and may become the first crop contributed to world agriculture by our state. We have collected plant and seed samples from over 90 different populations of the nearly 18 botanical species and varieties described so far. Studies of a majority of these species for genetic variation in morphology, pollination system, seed characteristics, and allozyme variation have shown that meadowfoam has a great potential for domestication and for improvement through breeding.

Field plantings at Davis during the past three years have shown that: (1) it is practical to prepare seedbed and seed with a drill as is done with cereals, (2) use of 7 to 8 kilograms of seed (average seed weight .004 to .005 gm) gives plant densities up to 200,000 per acre and yields up to 500 kg per acre, and (3) planted in November the crop is ready by the end of May. Although preemergence herbicides and other weed-control chemicals were not used, with normal rainfall (as in 1974-75) or irrigation the crop established itself very well. We are now investigating many details of agronomic practices.

In breeding work, some of our high priorities are: more upright winter growth and more synchronous branching; earlier maturity, to allow double cropping with rice; greater pollination efficiency leading to higher seed set per flower; and higher seed and oil yield. Seed size and oil content in various taxa are positively correlated, but their relationships with total yield per acre and fatty acid characteristics of the oil (a criterion of industrial quality) are not known. Different populations are being evaluated in the field for flowering and yield traits and for success in isolating superior genotypes. Since different species offer highly diverse agronomic features, hybridization with or without the use of polyploidy will be an important aspect of future research.

Germplasm collections

In the March 1977 issue of *California Agriculture,* we discussed the potential genetic resources in this genus. Further work this year has shown that seed collections from as many natural stands as possible should be made and conserved since various populations have a great deal of genetic diversity for both adaptational and agronomic traits. Some populations may become extinct due to habittat destruction or severe climatic stress, such as drought.

Most natural populations are rather limited as their habitat is largely confined to vernally moist meadows and streambeds, or vernal pools, and only a very small proportion of these habitable 'islands' in any area have *Limnanthes* in them. The genus as a whole is truly rare, endemic, and endangered, and therefore deserves urgent conservation efforts. Interest in crop development further warrants both conservation and research.

Both amaranth and meadowfoam illustrate that genetic resources in new crops pose a different set of questions than those in established crops. Instead of specific searches for resistance genes, or manipulation of genetic stocks for better combining ability, or studies on the cytogenetic relationships among parents of certain hybrids, we are dealing with the broad biosystematic studies of these genera that will provide a detailed picture of the distribution, adaptive features, and identification of various species, and initial agronomic efforts to improve plant type, yield, nonshattering of seed, and certain competitive traits. The broadest possible evaluation and documentation of genetic resources have to be efficiently combined with the desired expediency of agricultural improvements.

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