Vigna Germplasm:
Current Status and Future Needs

A report

prepared by the

Vigna Crop Germplasm Committee

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Introduction

The genus *Vigna* contains several species that are important in world agriculture. Cowpeas (*V. unguiculata*), mung beans (*V. radiata*), and urd beans (*V. mungo*) are grown on more than 10 million ha annually, and provide a significant portion of the dietary protein in many societies. Several other species, i.e., adzuki beans (*V. angularis*), moth beans (*V. aconitifolia*), rice beans (*V. umbellata*), and Bambarra groundnut (*V. subterranea*) are important in the diets of other societies. All of the cultivated *Vigna* species can be grown over a wide range of environmental conditions and all provide inexpensive protein available in several edible forms, such as tender green shoots and leaves, immature pods, and green and dry seeds. These species are also valued as fodder, cover, and green manure crops. Two of the species, the cowpea and the mung bean, are of economic importance in the United States.

The cowpea is one of the world's important legume food crops. Available estimates of worldwide cowpea production indicate that 1.5 to 2.25 million metric tons of dry seed are harvested annually from 5 to 7.5 million ha. In the United States, the cowpea is grown on a relatively large scale as a processing vegetable crop (southernpea), as a dry bean (blackeye pea, blackeye bean, field pea), and as a market garden crop (field pea, crowder pea, purple hull pea, etc.). Additionally, various types of cowpeas are popular home garden items in all of the southern states from Texas through the Carolinas and Virginia. Georgia, Arkansas and Tennessee are the leading producers of processing peas, and California and Texas are the leading producers of dry beans. It is estimated that 80,000 ha of cowpeas are grown in the United States each year.

The mung bean is widely grown in southern Asiatic countries. In the United States, it is the bean that is commonly used for sprouting. The Oriental restaurants and commercial processors in this country sprout 9 million kilos of mung bean seed annually. About one-fourth of these beans are grown domestically, primarily in Oklahoma.

Present Germplasm Activities

Much of the present *Vigna* germplasm evaluation and enhancement efforts in the United States is by horticultural plant breeders working for public agencies. Except for a small mung bean breeding program at Texas A & M University, virtually all of this work is with cowpea. A recent search of more than 30,000 research resumes in the USDA's Current Research Information System database (coverage includes projects conducted primarily by the research agencies of the U. S. Department of Agriculture, the state agricultural experiment stations, the state land-grant colleges and universities, Tuskegee University, and other cooperating institutions) identified 11 universities and one federal agency in the continental United States with active or recently completed cowpea breeding or germplasm evaluation projects. Cowpea breeding or germplasm evaluation research is being conducted in 13 states.

Seven of the universities (Auburn University, Louisiana State University, Purdue University, Texas A&M University, University of Arkansas, University of California at Davis, and the University of California at Riverside) and the Agricultural Research Service of the USDA had clearly identifiable cowpea breeding objectives. It should be noted, however, that the breeding program at Auburn University is inactive at present. Two other universities (New Mexico State University and University of Florida) have active cowpea cultivar evaluation research projects.

A number of universities have active research projects to develop improved technologies and methods that have possible application to cowpea breeding programs. For example, these projects are addressing such topics as the inheritance of economically important cowpea traits; the identification of new sources of tolerances to herbicides, seedling chilling, AL toxicity, CA deficiency, heat stress, and drought stress; identification of new sources of resistances to insects and nematodes; mechanisms of virus resistance; salt tolerance; ways to improve protein quality; ways to improve photosynthetic and nitrogen fixation efficiencies; and the development of improved procedures to evaluate various cowpea traits.

In 1988, the University of California at Riverside (UCR) and the USDA entered into the first of two Specific Cooperative Agreements to increase a large number of new accessions (primarily from the 12,000+ accessions held by the International Institute of Tropical Agriculture, Ibadan, Nigeria) for incorporation into the cowpea germplasm collection located at the USDA Regional Plant Introduction Station in Griffin, Georgia. The first agreement "Evaluation and Multiplication of Cowpea (*Vigna unguiculata*) Germplasm" was funded in the amount of $40,600.00 and was effective from 1 June 1988 through 30 September 1990. The second agreement “Characterization and Multiplication of Cowpea (*Vigna unguiculata*) Accessions” was funded in the amount of $46,000.00 and was effective 15 September 1991 through 30 September 1994. **The end result of UCR/USDA agreements was an approximately 200% increase in the size of the USDA cowpea germplasm collection** -- **<u>4,595 unique accessions were added</u>**. It should be noted that one of the objectives of these agreements was the elimination of viruses based on symptomology. Although successful for a large portion of the accessions, it proved to be unsuccessful for the exotic viruses present in some germplasm from Botswana, India, and Kenya.

Most cowpea breeding programs in the United States have short-term goals, i.e. the quick development of cultivars to meet immediate contingencies and industry requirements. Many of the general objectives are the same. Such traits as increased yield, concentration of pod set, superior plant habit, improved adaptation, and increased tolerances to environmental stresses are important. Resistances to fungal diseases (e.g., anthracnose, Cercospora leaf spot, Fusarium wilt, root rots, and Verticillium wilt), bacterial diseases (e.g., bacterial blight and canker), viruses (e.g., bean yellow mosaic, blackeye cowpea mosaic, cowpea chlorotic mottle, cowpea mottle, cowpea yellow mosaic, cucumber mosaic, and southern bean mosaic), root-knot nematodes (*Meloidogyne* spp.), and insects (e.g., cowpea curculio, aphids, and lygus bugs), particularly those that cause significant yield reductions, are universally important.

Several U. S. breeding programs have stated long-term objectives, e.g. improved breeding populations and conservation of genetic variability.

Regional testing of advanced cowpea breeding lines is coordinated by the Regional Southernpea Cooperative Trials. These trials are a part of the Southern Cooperative Vegetable Trials sponsored by the Southern Region of the American Society for Horticultural Science. The cooperative trials, in which lines are tested in many locations, provide breeders with as much information in a single season as they could obtain at a single location over many years. The southernpea trials are not intended to be a substitute for ordinary cultivar trials, and only advanced breeding lines are accepted for testing. The 1995 trials were grown at 10 sites in 6 different states; there was 10 entries in the replicated trial and 7 entries in the observational trial. The trials are planned, coordinated and reported annually by a chairman.

There is one commodity-oriented organization that plays an important role in coordinating U. S. cowpea germplasm evaluation and enhancement programs. This organization is the National Cowpea Improvement Association (formerly the Cowpea Improvement Committee), and it is open to all scientists with an interest in cowpea improvement. The organization, which is quite informal, meets annually, usually in conjunction with the annual meeting of the Southern Region of the American Society for Horticultural Science. The National Cowpea Improvement Association is the "parent organization" of the Vigna Crop Germplasm Committee.

The implementation of the Bean/Cowpea Collaborative Research Support Program (CRSP) in October 1980 with funds provided by the U.S. Agency for International Development under Title XII of the Foreign Assistance Act has played an important role in bringing together resources of institutions in the U.S. and those of institutions in Africa and Latin American. The Bean/Cowpea CRSP researchers have made many contributions toward resolving cowpea production and utilization problems in those countries where the crop is important in the human diet. As intended, many of these contributions are applicable to the cowpea industry in the U.S.

Status of Crop Vulnerability

Genetic vulnerability is not seen as a critical problem for the *Vigna* species grown in the United States. In comparison with many of the agronomic crops, cowpeas and mung beans are relatively minor crops in the U. S. Neither crop is considered to be staple food in U. S. society. Also, there are readily available and suitable substitute crops, e.g., the common bean (*Phaseolus vulgaris*) could be cultivated in lieu of the cowpea. The cowpea was once an important forage crop in the U. S., but there is only limited use of the crop as forage at present.

The economic *Vigna* species grown in the U.S. are not considered to be particularly susceptible to intentional sabotage by the use of any type of fungal or bacterial pathogen, nematodes, or insect pests. Some type of virus would most likely be the pathogen of choice for use by potential saboteurs. Viruses can be extremely devastating to *Vigna* plantings, and many are seed borne or can be easily spread by insect vectors or infected plant debris. For example, cowpea mottle, a severe cowpea virus common in Africa, is extremely stable and infectious. Intentional introduction of cowpea mottle virus into major U.S. cowpea production areas might have devastating consequences. The most feasible approach for addressing virus risks to cultivated *Vigna* species would be the development and use of resistant cultivars. As noted elsewhere in this report, there are a number of large national and international collections of *Vigna* germplasm that could be searched for sources of resistance to viruses.

There is a broad range in the characteristics of cowpea cultivars that are popular in the United States. There is a broad range of genetic diversity among cultivars. It is not anticipated that current breeding programs will have a significant impact on the diversity. In fact, the availability of new cultivars might decrease our dependence on some major cultivars that account for large portions of the production in some areas. For example, ‘California Blackeye #46', a new blackeye cultivar with increased resistance to Fusarium wilt, has greatly reduced our heavy dependence on 'California Blackeye #5' in the dry seed industry.

Germplasm Needs

Collections

There are large and diverse *Vigna* collections held in several international and national centers. The large numbers of unique accessions that have been added to the USDA cowpea germplasm collection since 1988 via the University of California at Riverside/USDA Specific Cooperative Agreements discussed above has greatly enhanced the adequacy of the USDA collection to meet U.S. cowpea germplasm needs.

The International Institute of Tropical Agriculture (IITA) cowpea base collection (12,000 - 13,000 accessions) is larger than the current USDA collection. The IITA collection is a very important collection, and a major effort needs to be made to store duplicate samples in the U. S. We do not have easy access to IITA materials at present, and the entire collection could be lost if there is a civil war in Nigeria. Museum storage under cold conditions, such as the National Seed Storage Laboratory (NSSL), would be appropriate.

The University of California at Riverside has an appreciable collection of cowpea germplasm (approximately 5,000 accessions) that was obtained from the USDA, IITA, and different countries as part of the Title XII Bean/Cowpea Collaborative Research Support Program. Many of these lines have been evaluated and increased as part of the UCR/USDA Specific Cooperative Agreements discussed above, and are now included in the USDA working collection.

There is currently a large collection of mung bean germplasm stored at the Asian Vegetable Research and Development Center. Consideration should be given to storing duplicates of this collection at the NSSL.

The National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India, maintains large collections of mung beans and urd beans (*V. mungo*). The urd bean crosses quite readily with the mung bean, and it should be considered part of the mung bean gene pool. Consideration should be given to storing duplicates of both collections in the U. S.

There is a problem of duplication in the U. S. collections, and the problem will become more serious as duplicates of other collections are accepted for storage. Effort are currently underway at the Plant Introduction Station in Griffin, Georgia, to develop the methodology needed to identify duplicates (synonyms).

The various *Vigna* collections described above represent a broad sampling of much of the world's gene pools. However, their are still centers of diversity that need sampling. The International Board for Plant Genetic Resources (IBPGR) publication "Genetic Resources of *Vigna* Species" (AGPG:IBPGR/81/82) assigned the following crop priorities (each entry in order of need) for exploration and collection:

Vigna radiata

Burma, China, Thailand
Afghanistan, Indonesia, Iran, Philippines
Malaysia
Eastern Africa, Madagascar, South Africa
Caribbean

Vigna mungo

Burma
Bhutan, Nepal
Bangladesh
Afghanistan, Iran
N. Malaysia, Philippines

Vigna unguiculata (cultivated forms)

Fernando Po, Mozambique, Zimbabwe
Botswana, Lesotho, South Africa, Swaziland
Central African Republic, Zaire
Angola, Congo, Gabon
Southeast Asia, China

Vigna unguiculata (wild forms)

South Africa (Natal and Transvaal), Zimbabwe
East African and Zambezian phytogeographical zones

The IBPGR publication also listed exploration and collection priorities for the following species: *V. umbellata*, *V. angularis*, *V. aconitifolia*, *V. nervosa*, and *V. subterranea*. These species are of potential value to U. S. research programs, and they should be included in any exploration effort to collect *Vigna* germplasm.

Evaluation

Much of the current *Vigna* germplasm evaluation work in the U. S. is being carried out as adjunct projects to plant breeding programs. Virtually all of this work is on cowpea. In general, these programs are doing a creditable job of addressing the high priority evaluation needs. An effort needs to be made to "educate" plant breeders about the value of putting evaluation data into the GRIN database. The two UCR/USDA Specific Cooperative Agreements discussed above have generated a large amount of evaluation data on the IITA and Title XII collections.

The USDA *Vigna* collection is currently located at the Plant Introduction Station, Griffin, Georgia. This station's evaluation work on *Vigna* germplasm has not been sufficiently active in recent years, but the establishment of a curator in early 1994 has begun to address this problem.

The *Vigna* Crop Germplasm Committee recently (4 February 1996) revised its list of priority evaluation needs for cowpea:

Virus resistances

Blackeye Cowpea Mosaic Virus (Arkansas strain)
Cucumber Mosaic Virus
Cowpea Mottle

Disease resistances

Ascochyta blight
Southern Blight
Choanephora pod rot
Charcoal rot

Insect resistances

Cowpea curculio
Cowpea aphid (vector; resistance especially needed for California biotype)

Lygus bug
Leaf miner

Enhancement

As was the case with germplasm evaluation, much of the current *Vigna* germplasm enhancement work in the U. S. is being carried out as adjunct projects to plant breeding programs. Like the germplasm evaluation work, virtually all of the *Vigna* germplasm enhancement work is on cowpeas.

U. S. cowpea breeders face formidable challenges in developing new cultivars suitable for modern, highly specialized production and marketing systems. Cultivars are needed that exhibit increased resistance to a wide array of diseases, insects, and nematodes, better tolerances to environmental stresses, increased nitrogen-fixing capacity, better seed qualities, and improved efficiency in the utilization of limited soil nutrients. The plant breeder has an obligation to improve the nutritional, flavor and aesthetic aspects of cowpea products. The plant breeder can play an important role in the development of improved production systems. For example, cultivars with modified growth habits might be used to increase production efficiency in intensely managed farming systems. Weed problems might be solved by developing cultivars with tolerance to existing herbicides. In comparison with many other crops, the cowpea has received little attention from plant breeders, and a large effort needs to be made to break yield barriers.

If American cowpea breeders are to be successful in addressing the needs of modern agriculture, appreciable amounts of effort will have to be directed to germplasm enhancement. The genes needed to develop the truly revolutionary cultivars of tomorrow exist now only in exotic genetic backgrounds (extensive cowpea germplasm collections are held by various national and international agencies). It is anticipated that much of the future germplasm and evaluation work will continue to be adjunct projects of ongoing plant breeding programs. For the most part, germplasm evaluation should be limited to those traits of immediate concern to plant breeders. The individuals evaluating germplasm can be expected to be charged with the responsibility of directing developmental breeding programs (germplasm enhancement) to transfer newly identified and potentially valuable genes into cultivar materials. It is recommended that the bulk of the monies (70-85%) available for germplasm collection, evaluation and enhancement be directed toward enhancement.

The *Vigna* Crop Advisory Committee recently (4 February 1996) updated its list of priority enhancement projects for cowpea:

Development of better techniques for evaluation and enhancement of germplasm for virus resistance, e.g., BlCMV and CSMV

Development of a genetic map

Yield concentration (synchronous flowering; less insecticide needed for controlling cowpea curculio)

Development of better techniques for evaluation and enhancement of germplasm for processing quality (especially seed stain)

Development of germplasm with wider maturity ranges (late maturing cultivars are especially needed)

Bacterial blight resistance

Heat tolerance (needed for fall production)

Resistance to insects, e.g., cowpea curculio, lygus bug, leaf miner, cowpea aphid

Resistance to Cowpea Severe Mosaic and Blackeye Cowpea Mosaic Viruses

Combine resistance (resistance to seed damage)

Improved seed quality, e.g., splits and fish mouth

Preservation (storage)

The base USDA *Vigna* germplasm collections are held at the National Seed Storage Laboratory (NSSL) in Fort Collins, Colorado, and the USDA working collections are held at the Plant Introduction Station in Griffin, Georgia. Storage conditions are adequate at both locations. Procedures for preserving genetic diversity in samples are adequate.

The working *Vigna* collections at Griffin contain a total of 12,496 accessions, including 7,698 cowpea accessions, 3,890 mung bean accessions, 306 urd bean accessions, 498 Bambarra groundnut accessions, and a small number of accessions (total = 104) for each of several of the minor cultivated and wild species.

In 1995, The Vigna Crop Germplasm Committee established a core subset of the USDA cowpea germplasm collection. The subset consists of about 9% (700 accessions) of the 7,698 accessions currently contained in the collection. The subset was selected on the basis of country of origin, taxonomic characteristics, and known disease and pest resistance characteristics.

Most of the accessions in the *Vigna* working collections at Griffin are not backed up in the base collections at the NSSL, but a major effort is currently being made to correct this problem. There are now 1,300 cowpea accessions backed up, and 2,500 additional cowpea accessions will be backed up by Spring 1996. Most of the cowpea accessions increased in recent years by UCR, and now in storage at Griffin, will also be backed up at NSSL in 1996.

Several of the nation's cowpea breeding programs (including some inactive programs) maintain small working collections. There is no good procedure in place to insure that the potentially valuable materials in some of these collections are incorporated into the base collection.

Recommendations

In many respects, the location of the USDA *Vigna* working collection at Griffin, Georgia, is not a good location for cowpea grow-outs and evaluation. Griffin is located just north a major cowpea (southernpea) production area, and it is risky to produce cowpea seed here because lines readily become reinfected by endemic viruses. Also, Griffin is not adequate for increase of photoperiod-sensitive lines. A site in southern California, e.g., Riverside, would be a better location for grow-outs and evaluations of the working collections. Such a location would provide a hot, dry, pest- and disease-free growing environment, and a very low (negligible) level of outcrossing. However, it should be noted the even Riverside is not far enough south to adequately increase seed of some extremely photoperiod-sensitive lines. Increase sites in Hawaii or the Virgin Islands would probably have adequate photoperiods for these “hard-to-increase” lines. (Note: University of California researchers have successfully increased “very photosensitive” cowpea accessions by using mid-August plantings at a low-elevation desert site 40 miles south of Palm Springs, CA.)

Virus diseases pose the greatest threat to cowpea production in the southern states. Special efforts need to be made to identify sources of virus resistances and to transfer such resistances into cultivar-type materials. This needs to be an ongoing effort since new races/strains of each problem virus are likely to overcome currently available sources of resistances.

Breeding cowpeas for resistance to the most destructive pathogens has been an effective method of minimizing disease losses in the U. S., but much more work is needed. Sources of resistance to many fungal and bacterial diseases need to be identified, and developmental breeding efforts need to be expanded to incorporate new resistance genes into advanced breeding lines.

Insects (e.g., cowpea cucrulio, cowpea aphid, lygus bug, and leaf miners) are major pests of the cowpea, and the problem has intensified in recent years because of the withdrawal of pesticide registrations. In fact, the unavailability of suitable pesticides has already caused a major shift in the geographic areas where southernpeas are grown for processing. Better sources of resistances to insects are badly needed.

Breeding for all types of pest resistances (whether against insects, nematodes, fungal pathogens, bacterial pathogens, viruses, or weed pests) has a common environmental justification -- alternatives are needed to pesticides. The southernpea and blackeye bean industries are heavily depended upon pesticides, and every effort needs to be made to find alternatives!

Compared with many other crops, the cowpea has received little attention from plant breeders, and a large effort needs to be made to break yield barriers. Cowpea yields have never equaled the yields that are expected of such food legume crops as lima beans. If cowpea production is to keep pace with these crops, its yield potential must be improved.