Chapter II

Breeding Beans and Cowpeas for Drought Resistance and Heat Tolerance

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SUMMARY

This international cooperative experience with plant breeding provides insights for expanding food production in U.S. semiarid lands. In particular:

- beans and cowpeas are dryland staples in many developing countries and, in the future, they may provide an alternative dryland crop for U.S. semiarid lands;
- collaborative plant breeding programs are expected to increase the productivity of these crops under conditions of drought and heat stress by combining native varieties of Central American and African plants with high-yielding Californian strains; and
- this international research has benefited foreign farmers and U.S. researchers and shows potential for directly benefiting American farmers and consumers.

INTRODUCTION

Traditionally, plant breeding and testing have focused more on improving yield, quality, and resistance to disease and less on adapting plants to natural environmental stresses. Recently, however, problems associated with environmental stresses such as heat, drought, and salinity have attracted more attention. About four-fifths of the gap between average and record crop yields in the United States results from such stresses. The factors that make plants do better or worse under stress are not well understood. One path to such understanding is through crossbreeding of high-yield strains with those that have survived under harsher climates and conditions.[1]

Some crops grown in the United States under rainfall or irrigation have the potential for being grown with less water and producing higher and more stable yields. Beans (common beans that are grown to produce dry beans) and cowpeas are two semiarid crops with such characteristics. Both are legumes and have long been grown overseas under dryland farming regimes that have produced hardy strains. In Senegal, for instance, the local cowpea is so hardy it has been called "the crop of security." The cowpea and bean have been dependable crops, producing food in arid and semiarid regions when sorghum and pearl millet crops failed.'

For many developing countries, beans and cowpeas are dietary staples. In Mexico, for example, where 40 percent of the bean production comes from semiarid lands, beans are a staples These legumes provide a major source of high-quality and affordable protein and carbohydrate. In addition, they are an important source of the B complex vitamins.[4] For this rea-

[1] B. Hiatt, "To Increase Survival, " Mosaic (Washington, D. C.: National Science Foundation, May-June 1982), p. 27.

[2] A. E. Hall, "International Cooperation in Agricultural Research to Develop Improved Cowpea Cultivars for Semiarid Regions of Africa and the United States, " Office of Technology Assessment commissioned paper, April 1982. Supplemented by telephone interview with Dr. Hall, University of California (Riverside), April 1982.

[3] M. Wayne Adams, Michigan State University, former director of the Bean/Cowpea CRSP, April 1982, telephone interview.

[4] *Annual Report of the Bean/Cowpea Collaborative Research Support Program (CRSP)* 1981, Bean/Cowpea CRSP Management Office Staff, Michigan State University (East Lansing, Mich.: December 1981).

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son, U.S. technical assistance programs have focused on these legumes as a possible means of improving food and nutrition abroad, particularly for subsistence and low-income peoples.

COLLABORATIVE RESEARCH SUPPORT PROGRAM

In September 1980, the Bean/Cowpea Collaborative Research Support Program (CRSP) was established through funds from the U.S. Agency for International Development (AID) under Title XII of the Foreign Assistance Act of 1975.[5] The purpose of the program has been to help eradicate hunger and malnutrition in Africa and Latin America. The program's research focus is on the production and use of dry beans *(Phaseolus vulgaris* L.) and cowpeas or black-eyed peas *(Vigna unguiculata* (L.) Walp.). Research on environmental stress on these plants is a major component.[6]

The Bean/Cowpea CRSP is managed by Michigan State University. Nine other universities also participate. The collaborating countries include Brazil, Cameroon, the Dominican Republic, Ecuador, Guatemala, Honduras, Kenya, Malawi, Mexico, Nigeria, Senegal, and Tanzania. The total fiscal year 1981 contributions by all parties are shown in table 3. About 25 percent of the total U.S. contribution comes from private and public U.S. institutions, reflecting some sense that potential benefits might accrue to U.S. agricultural research interests, especially the private sector. A description of the CRSP bean projects in Guatemala and Mexico and the cowpea project in Senegal follows, to illustrate the kinds of activities and benefits coming from the Bean/Cowpea CRSP.

Bean CRSP--Guatemala[7]

Cornell University and the Instituto de Ciencia y Technologiá Agrícolas (ICTA) of Guate-

[5] The Bean/Cowpea CRSP is one of several programs funded by AID. CRSPs generally involve U.S. universities, research institutions in developing countries, and international agricultural research centers. All contribute resources to the projects. Their main purpose is to assist development of research capacities abroad, but they are also designed to benefit U.S. agriculture. The description of CRSP is from Bean/Cowpea CRSP Annual Report and An *Assessment of U.S. Food and Agricultural Research* (Washington, D. C.: Office of Technology Assessment, U.S. Congress, 1981), p. 164.

[6] *Annual Report,* op. cit.

[7] *Annual Report,* op. cit., app. D.

Table 3.—Fiscal Year 1981 U.S. Financial Commitments to Bean/Cowpea CRSP Projects

Country/institution	Plant	U.S. AID contribution	U.S. institution contribution	Percent of total project contribution from U.S. institution
INCAP,[a] Central America/Washington State	Dry bean	$159,700	$73,130	31'!0
Honduras/Puerto Rico	Bean	50,500	20,075	28
Guatemala/Cornell	Bean	89,250	27,871	24
Brazil/Wisconsin	Bean	83,900	11,617	12
Brazil/Wisconsin	Bean	83,900	26,809	24
Brazil/Boyce Thompson Institute	Cowpea	83,900	29,704	26
Dominican Republic/Puerto Rico	Bean	92,350	31,168	25
Dominican Republic/Nebraska	Bean	92,350	48,320	34
Senegal/UC-Riverside	Cowpea	140,000	48,830	26
Cameroon/Georgia	Cowpea	126,000	31,546	20
Nigeria/Michigan State	Cowpea	67,200	31,542	32
Nigeria/Georgia	Cowpea	67,200	21,333	24
Kenya/UC-Davis	Bean	134,400	44,840	25
Tanzania/Washington State	Bean	117,460	63,682	35
Malawi/Michigan State	Bean	92,482	12,928	12
Total		$1,480,592	$523,395	260/o

[a] Institute for Nutrition in Central America and Panama.

SOURCE: *The Annual Report of the Bean/Cowpea Collaborative Research Support Program (CRSP), 1981,* Bean/Cowpea CRSP, Management Office Staff, Michigan State University, December 1981.

mala are collaborating on bean research to determine, on a worldwide basis, how variations in day length and temperature affect plant development, maturity, and adaptation. These plant characteristics, in turn, affect how much water a crop requires. Cornell University scientists have found, for instance, that the time it takes the bean plant to grow to the flowering stage is important in determining its yield. The time factor, in turn, is influenced by length of daylight and day/night temperature differences.

A number of factors make U.S.-Guatemalan cooperation in this research beneficial. Plant geneticists who work on breeding to produce a particular characteristic, such as optimum time from planting to flowering, need a variety of beans with that characteristic from which to draw genetic material. Guatemala, one of the areas in Central America where the bean originated, offers a greater diversity of bean plants than does the United States, since the plant has had a comparatively longer time to develop there. Guatemala also has both high and moderate altitude locations in close proximity. This provides a greater variety of day/night temperature ranges in which to field-test new strains.

Bean CRSP--Mexico[8]

Collaborative bean research began in 1982 between the Instituto Nacional de Investigaciones Agrícolas (INIA) in Durango, Mexico, and U.S. universities. Two initial considerations make Mexico a natural partner for bean research. First, the bean originated in the highlands of Mexico as well as Guatemala. Thus, the genetic material available in Mexico also is rich in diversity. Second, Mexico is the second largest bean-producing nation in the world.

The United States and Mexico have collaborated on research in two specific areas. Mexican researchers have made some progress developing bean varieties that are drought resistant. U.S. researchers have worked on improving the process by which beans convert atmospheric nitrogen to a usable form, allowing production without the need for supplemental nitrogen fertilizer. If drought resistance and greater biological nitrogen fixation can be merged, bean farmers in both countries may be able to get along with less fertilizer and water, Drought resistance in bean production may not seem immediately critical to U.S. agriculture. However, beans already are grown in some semiarid U.S. areas, and nationally the bean is a major crop. As world food demand increases, production of drought-resistant beans on U.S. water-limited lands may become increasingly important to make optimal use of those lands and help meet world food needs.

The second area that the joint Mexico/U.S. bean research has been pursuing is the further development of strains with a structural adaptation that deters water loss through transpiration. Such bean plants turn their leaves in dry periods so that the surface through which water is lost is pointed away from the Sun. Five of the top yielding strains of beans being researched through this program at Michigan State University have this capability.

Cowpea CRSP--Senegal[9]

The Cowpea CRSP is especially active between the University of California at Riverside and the Senegalese Institute for Agricultural Research, This program began 6 years ago as a small component of an AID-funded effort by UC/Riverside to assist with rural development in semiarid Africa with emphasis on the Sahel. The principal reasons that Senegal was so attractive for this collaborative research were that: 1) the cowpea probably originated in Africa, and 2) Senegalese plant breeders had begun using the available diverse cowpea genetic stock to develop cowpeas specifically adapted for semiarid zones.

The objectives of the cowpea research program include: 1) developing improved cowpea varieties and management methods for subsistence farmers in the semiarid zone of Senegal, and 2) developing cowpea varieties with im-

‘3 Adams interview, op. cit.

[9]Ibid.

proved drought adaptation, heat tolerance, and yield stability for use in semiarid zones throughout the world, including the United States.[10] During the first 2 years (1980-82) of the project, a number of significant findings were made by the joint efforts of U. S., Senegalese, and other researchers. The major findings follow.

Improving Drought Adaptation

Field screening techniques are being used in California to select cowpeas with: 1) roots more able to extract water from the soil, 2) earlier flowering, and 3) greater proportions of total carbohydrate in the pods. For example, some of the material produced will mature in 60 days, the length of the short rainy season in parts of Africa. Cowpeas with these improved characteristics are being crossed to produce superior progeny. About 30 of the advanced cowpea lines originating from crosses between Senegalese and Californian cowpeas have been evaluated for drought resistance and yield stability in cooperative tests in Senegal and California.

Screening for Heat Tolerance

Hot weather in both Africa and the United States causes flowers to drop and therefore pods never form. This reduces cowpea yields. Research by a Sudanese student at UC/Riverside has established a connection between excessive flower drop and high night temperatures just before flowering. Cowpeas from throughout the world have been grown during hot weather in the Imperial Valley, Calif., to search for strains with tolerance to heat. Two African strains were discovered that have greater heat tolerance than both the local varieties grown by farmers in Senegal and the blackeye pea types grown in California.

The challenge in research is to overcome the problems caused by the harsh environments in semiarid zones by breeding into the high-yielding California varieties the heat tolerance and drought adaptation characteristics identified in the more hardy Senegalese and other African cowpeas. According to one UC/Riverside scientist on the project, "the cooperative yield tests have demonstrated that some of the advanced cowpea lines are adapted to California and have improved drought resistance, whereas other lines are extremely early and require only 60 days from sowing to harvest in African conditions. During extreme droughts, with a short rainy season, these early lines have the potential to produce substantial yields while most cowpeas would fail to produce seed."[11]

[10] Hall, op. cit., pp. 1-2.

[11] Ibid., pp. 3-4.

TECHNOLOGY TRANSFER CONSIDERATIONS

The bean/cowpea collaborative research projects are relatively new and have not yet been implemented directly in commercial agriculture. Initial signs indicate, however, significant potential for improved bean and cowpea yields and water use efficiency through this collaborative plant breeding research. Cowpea varieties developed by this program with improved drought-resistance and heat-tolerance characteristics could increase the productivi-

ty and profitability of dryland and irrigated agriculture in semiarid regions of both developed and developing countries.

Agricultural productivity of arid and semiarid lands will become increasingly important to help meet growing food demands. Crops such as the cowpea may not now be of major importance to U.S. diets, but they could become an important export crop in the years ahead. This could become a factor in helping maintain a favorable U.S. balance of payments as well as providing a means of foreign assistance. Such foodstuffs would be particularly important for feeding children and pregnant women in countries where protein shortages develop.[12]

Promotion of this collaborative research and its potential benefits depends almost entirely on efforts of the involved scientists. In the views of some United States scientists participating in this international research, general U.S. interest in and use of the knowledge generated so far is insignificant. The matter has been given little attention by the U.S. Government.[13] In contrast, both Canada and Australia have specific organizations and programs designed to encourage international agricultural collaboration for use in foreign assistance as well as in their own agriculture.[14] The benefits to U.S. agriculture from the brief collaboration to date in the Bean/Cowpea CRSPs suggest that more U.S. participation in this kind of international research could provide important future benefits for U.S. farmers in arid and semiarid agriculture,

[12] Hall interview, op. cit.

[13] *An* Assessment *of U.S. Food and Agricultural* ***Research, op.*** cit., pp. 151-169 (see footnote 5).

[14] Donald Plucknett, Science Advisor to the CGIAR Secretariat, World Bank, May 1982, telephone interview.