The Dakar Symposium/Workshop on the Genetic Improvement of Cowpea

January 8 –12, 2001

The conference organizers gratefully acknowledge the
contributions made to this conference by the
following organizations.

The Rockefeller Foundation

The Bean/Cowpea Collaborative Research Support Program - (CRSP)

The International Institute of Tropical Agriculture – (IITA)

Institut Sénégalais de Recherches Agricole - (ISRA)

The Food and Agricultural Organization, Harare Office, Zimbabwe

Purdue University

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Welcoming Remarks
Senegal Minister of Agriculture
The Honorable Pape Diouf

Rockefeller Foundation, FAO representative, scientific coordinator of this workshop, invited ladies and gentlemen, dear participants;

I would like to welcome you and wish you a good stay. On behalf of the Head of State, President Abdoulaye Wade, his government, and the people of Senegal. We are particularly proud that you have chosen Dakar to organize this workshop with the theme "Genetic Improvement of Cowpeas."

If I readily accepted to preside at the opening of this symposium/workshop, it is because it is a theme of interest to my Ministry of Agriculture, which also sponsors national agricultural research. In fact, cowpea constitutes one of the most important food crops in Senegal and the Sahel. Its importance results from its adaptation to the semi-arid zones of Africa and its high content of quality proteins. It is extremely well adapted to the North and Central North region of the Senegalese peanut basin, where rainfall is low and sporadic. In these arid zones, cowpea is one of the few crops that can reach maturity. It is widely consumed and commercialized as "green bean" from mid-August. Cowpeas play a vital role in rural areas during the hungry season and also contribute to assure food security. Cowpea also constitutes an important element in the stabilization and improvement of soil fertility through its symbiotic fixation of atmospheric nitrogen.

However, different biotic and abiotic constraints limit cowpea production. Among those constraints are various insects which are very damaging. Considerable losses have often been observed depending on the zone, year and varieties used. These losses could be minimized by using insecticides; however, the majority of African producers do not use chemical products since they cannot afford them. The development and extension of insect-resistant varieties constitutes a more economical and better ecological alternative. Unfortunately resistance genes to certain diseases have not been found in cowpea, making it difficult to genetically control them.

Your workshop therefore has the general objective of reviewing the state-of-the-art applications of biotechnology to improve cowpea, in order to find ways and means to create genetically modified varieties. I encourage you in your general approach to pull together human and material resources from your various institutions and research disciplines to transform cowpeas.

These several days of discussions and exchanges should allow you to increase your understanding, motivation and strategies to begin to:

- Develop an efficient, reliable and replicable system to genetically transform cowpeas.
- Evaluate the quality of the end product in order to protect the consumer's well-being
- Conduct economic studies to formulate means and ways to optimize the dissemination and adoption of cowpeas improved by biotechnology.
- To set up mechanisms so that intellectual property rights are protected or readily available.
- Assure that the governments of Africa have available the necessary regulatory infrastructures to responsibly evaluate nutritional and environmental problems resulting from biotechnology products.
- Organize public education programs with objective and balanced presentations concerning positive and negative effects associated with the adoption of these new technologies.

Wishing you success in your endeavors, I declare open the Symposium on the Genetic Improvement of Cowpea.

Thank you,
The Honorable Pape Diouf
Minister of Agriculture

Monsieur le Représentant de la Fondation Rockfeller, Monsieur le Représentant de la FAO, Madame la Représentante du Projet CRSP / Haricot et Niébé, Monsieur le Coordonnateur Scientifique du séminaire, Mesdames et Messieurs les invités, Chers Participants,

Je voudrais tout d'abord, aux noms du chef de l'état, le président Abdoulaye Wade, de son gouvernement, et de l'ensemble du peuple Sénégalais, vous souhaiter la bienvenue et un bon séjour parmi nous. Nous sommes particulièrement fiers que vous ayez choisi Dakar pour organiser ce séminaire ayant pour thème « l'application de la biotechnologie à l'amélioration génétique du niébé.

Si j'ai accepté volontiers de présider la cérémonie d'ouverture de cet atelier, c'est parce que son objet intéresse à plus d'un titre mon département en tant que Ministère de l'agriculture et de tutelle de la Recherche agricole nationale. En effet, le niébé constitue l'une des plus importantes plantes de culture vivrière au Sénégal et au Sahel. Son importance résulte de son adaptation aux zones semi-arides de l'Afrique et de sa teneur élevée en protéines de qualité. Il est particulièrement bien adapté au Nord et Centre Nord du bassin arachidier Sénégalais, dont la pluviométrie est faible et aléatoire. Dans ces zones de sécheresses, le niébé y est l'une des rares spéculations à atteindre la maturité. Il est fortement consommé et commercialisé comme « haricots verts », dés la mi - Août. Il joue ainsi un rôle vital en milieu rural pendant les périodes de soudure et contribue aussi à assurer la sécurité alimentaire des populations. Le niébé constitue également un élément important dans la stabilisation et l'amélioration de la fertilité des sols, par sa fixation symbiotique de l'azote atmosphérique.

Cependant différentes contraintes biotiques et abiotiques limitent les rendements du niébé. Parmi lesquelles, différentes espèces d'insectes constituent les plus dommageables. Des réductions souvent considérables de rendements dues aux insectes, sont régulièrement observées en fonction des zones, de l'année et des variétés utilisées. Ces pertes peuvent être minimisées par l'application d'insecticides. Cependant la majorité des producteurs africains n'utilise pas de produits chimiques, parce qu'ils ne peuvent pas se les offrir. Le développement et la vulgarisation de variétés résistantes aux insectes constituent une alternative plus économique et plus écologique. Malheureusement des gènes de résistance à certaines maladies n'ont pu être trouvés dans le niébé, rendant difficile le contrôle génétique de ces derniers.

Les nouvelles techniques de la biologie moléculaire et cellulaire ont récemment permis de transférer des gènes d'un organisme à un autre. Des variétés de coton, de maïs et de pommes de terre génétiquement modifiées et résistantes aux insectes sont aujourd'hui largement utilisées aux Etats-Unis. Les superficies cultivées en variétés de plantes génétiquement modifiées dans ce pays, ont atteint environ 35 Millions d'hectares en 1998. La biotechnologie a donc un futur prometteur ; son avantage est qu'elle peut résoudre des problèmes qui autrement ne le seraient pas. C'est le cas avec le niébé, dont le génome ne contient pas de gènes de résistance contre certaines espèces d'insectes. Il faudrait cependant s'entourer d'un minimum de garantie sur les conséquences pour l'homme et l'environnement des organismes génétiquement modifiés.

Votre séminaire a donc pour objectif général de faire l'état des lieux de l'application de la biotechnologie à l'amélioration du niébé, afin de dégager les voies et moyens de créer de nouvelles variétés génétiquement modifiées. Je vous encourage dans votre approche générale de mettre en commun les ressources matérielles et humaines de plusieurs institutions et disciplines de recherches pour arriver à transformer le niébé.

Ces journées de réflexion et d'échange devront vous permettre de comprendre d'avantage, les motivations et stratégies à mettre en œuvre pour :

- Développer un système efficace, sûr et reproductible de transformation génétique du niébé.
- Evaluer la qualité des produits résultants, afin de préserver la santé des consommateurs.
- Mener des études économiques pour formuler les voies et moyens d'optimiser la dissémination et l'adoption de niébé amélioré par la biotechnologie.
- Mettre en place des mécanismes pour que les droits à la propriété intellectuelle soient protégées ou librement disponibles.
- Assurer que les gouvernements d'Afrique disposent des structures nécessaires de régulation pour évaluer d'une façon responsable les problèmes de nutrition et d'environnement, posés par les produits de la biotechnologie.
- Organiser des programmes d'éducation du public avec une présentation objective et équilibrée des effets positifs et négatifs associés à l'adoption de ces nouvelles technologies.

En souhaitant plein succès à vos travaux, je déclare ouvert le séminaire sur l'application de la biotechnologie à l'amélioration génétique du niébé.

Je vous remercie.
Son Excellence Pape Diouf
Ministre de l'Agriculture

EXECUTIVE SUMMARY

A Symposium and Workshop on the genetic improvement of cowpea was held January 8-12, 2001, in Dakar, Senegal. The meeting was attended by 48 scientists and administrators representing a wide spectrum of the cowpea stakeholder community. Goals were (1) to assess the state-of-the-art as regards the genetic improvement of cowpea, and (2) to devise plans and new initiatives to address constraints to the production and availability of cowpea as a source of food and income. Special focus was given to the application of molecular biology tools for improving cowpea. Participants recognized that marker-assisted breeding and the development of an improved genetic map of cowpea offer ways and means to bring genetic improvements to this important African crop. Genetic transformation techniques likewise have promise to enable the introduction of badly needed traits -- such as resistance to the legume pod borer, Maruca vitrata -- traits not available through traditional breeding methods.

Participants included cowpea breeders, integrated pest management (IPM) specialists, food scientists, economists, intellectual property experts, policy analysts, research administrators, as well as molecular biologists. They came from nine African countries (Benin, Burkina Faso, Ghana, Kenya, Mali, Nigeria, Senegal, South Africa, and Zimbabwe), as well as from several universities, the private sector seed industry, and non-governmental and donor organizations from Africa, Australia, North America and Europe. Scientists participated from the International Institute for Tropical Agriculture (IITA), the Bean/Cowpea CRSP, and the United Nations Food and Agriculture (FAO) Subregional Office for Southern & Eastern Africa. Local support was provided by the Senegalese Institute for Agricultural Research (ISRA), which hosted the conference. Sponsoring organizations included the Rockefeller Foundation, the Bean/Cowpea CRSP, IITA, FAO, and ISRA. The meeting was organized by Larry Murdock with the help of many others; CRSPer Ndiaga Cisse of ISRA handled local arrangements.

At the close of the meeting the participants elected Idah Sithole-Niang of the University of Zimbabwe, Harare, and Larry Murdock of Purdue University, West Lafayette, Indiana, USA, as co-chairs of the new initiative -- called the Network for the Genetic Improvement of Cowpea for Africa (NGICA).

NGICA exists to foster the genetic improvement of cowpea for the benefit of low resource farmers and consumers in Africa and beyond, through a coordinated, comprehensive program of research, development and extension in the areas of food safety, environmental safety, public policy, public information, economics, seed delivery, as well as traditional and molecular genetics, entomology, IPM and plant breeding. Since the meeting in Dakar, NGICAns have been (1) actively developing detailed plans and initiatives to address key constraints to the genetic improvement of cowpea; (2) strengthening linkages between NGICA and the private sector; (3) developing a comprehensive NGICA document, and (4) seeking funding for specific NGICA research, development and public information initiatives.

BACKGROUND

Cowpea

Cultivated cowpea was originally an inconspicuous little wild plant that crept among the rocks of the dusty southern Sahel in north central Africa. It was domesticated thousands of years ago. Today, the genetic descendants of those wild plants are grown, as local or improved cultivars, on tens of millions of smallholder farms in the drier zones of Africa, in a great arc from Senegal eastward to Sudan and Somalia and southward to Zimbawe, Botswana and Mozambique. Two hundred million children, women and men consume cowpea often, even daily when it is available. It is widely acknowledged to be a crop of the poor.

Cowpea is a nearly perfect match for the African soil, the weather, and the people. Its grain is rich in protein and digestible carbohydrate; its energy content is nearly equal to that of cereal grains. Combined with cereals in the diet, lysine-rich cowpea complements the lysine-poor cereals, while the cereals supply the sulfur-containing amino acids needed for a balanced amino acid intake.

The tender leaves of the plant are nutritious as well; these contain 25% protein as a percentage of dry weight, and the protein quality is high. In many areas of Africa fresh leaves are regularly harvested and consumed, often as part of the typical “sauce”. The US National Aeronautics and Space Administration is so impressed with the nutritional potential of cowpea leaves that they are considering growing cowpeas in future space stations as food for astronauts.

In some areas of Africa, cowpeas are cooked as green pods, and the swollen beans consumed. These fresh cowpea pods, together with fresh green leaves, are the earliest foods available at the end of the “hungry time”. The succulent leaves can be harvested as soon as 21 days after planting, and cultivars are available that produce harvestable grain after only 60 days.

In many regions, cowpea hay is valued highly as fodder. This is harvested after the pods are picked. In some areas of Mali and Niger, the hay is the most valuable product of cowpea.

Like other legumes, cowpea fixes atmospheric nitrogen, and thus contributes to the available N levels in the soil. Often intercropped with sorghum, millet or maize, transfer of cowpea-fixed N to the cereal fosters cereal growth and increases yields. In farming systems where cowpea grown in monocrop is rotated with a cereal, the residual N from the cowpea benefits the cereal in the subsequent season.

One of the more remarkable things about cowpea is that it thrives in dry environments; cultivars are available that produce a good crop with as little as 300 mm of rainfall. This makes it the crop of choice for the Sahelian zone and the dry savannahs, though cultivars that flourish in the moist savannahs are available as well.

The deep root systems of cowpea help stabilize the soil, and the ground cover it provides preserves moisture; these traits are particularly important in the drier regions, where moisture is at a premium and the soil is fragile and subject to wind erosion.

Who Grows Cowpea?

The majority of cowpea growers are women. They grow cowpea because it provides food for their families, and they can sell the grain in local markets, or to traders, generating cash for household needs. The typical woman cowpea grower has a small plot, 0.25 to 1 ha., where she plants cowpea intercropped with sorghum or millet or maize.

Many men grow cowpea as well, in similar ways to those used by women. In some cowpea growing areas, men tend to grow it as a sole crop rather than as an intercrop. The grain they produce is more likely to be sold in the market or to traders, rather than consumed at home.

The leading cowpea growing countries are Nigeria and Niger, but the land area planted to cowpea is substantial in many other nations in sub-Saharan Africa, including Senegal, Mauritania, Mali, Burkina Faso, Côte D'Ivoire, Ghana, Benin, Togo, Chad, Cameroon, Central African Republic, Congo, Sudan, Ethiopia, Kenya, Angola, Somalia, Zambia, Mozambique, Zimbabwe, Botswana, Namibia, and South Africa.

Cowpea is an important crop in some countries in Latin America, especially in northeastern Brazil. In the USA, there is considerable cowpea production in California, Texas, Arkansas and the southeastern states. Most production is for the dry grain, but in the US southeast it is grown primarily to serve the fresh and frozen market.

Why Cowpea?

1. It would benefit women in sub-Saharan Africa in particular. They and their families would benefit from higher protein diets and the increased cash incomes from selling part of their crop in local markets. In many agricultural improvement projects, women farmers have gotten too little attention.

2. Cowpeas thrive in low rainfall areas where other crops do poorly. Cowpea is an excellent crop because of its low moisture requirement. In these areas, cowpea is the only legume that can thrive. These areas are among the most economically disadvantaged.

3. The soil stabilization and enrichment characteristics of cowpea are an important factor in a continent where the traditional fallow is disappearing.

4. Cowpea has received relatively little attention by international donors. It is unclear why this is so. It may be that international donors are unfamiliar with the crop and don't realize its potential for development. There may be cultural bias

5. against the crop on the part of the African power elites, who see it as a minor crop of the poor, with little prospect for development.

6. It could contribute toward increasing the availability of food since there is a prospect of substantial increases in production on current land areas.

7. Cowpea-based value-added products can be developed. These would benefit cowpea producers by increasing the size and stability of the market. They would benefit consumers by saving labor as well as increasing the nutritional value of their food. Adoption of cowpea-based value-added products has already begun in Senegal and Mauritania.

8. Cowpea can be used to prepare high-protein infant foods. In some areas, such as Senegal, cowpea-based infant foods are already commercially available on a widespread basis. In many areas, it may be preferable to use soybean for infant foods because of its higher energy density and higher protein content. But in some areas soybean is not an alternative.

9. The private sector can get involved. There are opportunities for entrepreneurs in seed production/distribution and trade in cowpea grain as well as value-added products. Because cowpea is a traditional crop of Africa, trade is in the hands of Africans. As regards international trade outside Africa – there are potential markets in Brazil and Europe – grain marketing and quality standards will need to be developed. In Cameroon, where the trading system in cowpea is currently being characterized, a network of people is involved, including (a) producers, (b) the buyer in the village who assembles 100 kg bags of grain, (c) the village warehouser who stores the bags until the grain is loaded onto trucks, (d) truckers, (e) warehouse operators as the grain is in transit, (f) laborers who handle the grain as it is moved along the way to market, (g) business people who sell the grain in markets, (h) small-scale entrepreneurs who make and sell products like akara (a deep-fried cowpea cake) and other cowpea-based street foods.

10. Mechanisms to transfer improved cowpea technology are becoming available. Examples of this include the collaboration between technology-producing projects like the Bean/Cowpea Collaborative Research Support Program (CRSP) and extension-oriented non-governmental programs like World Vision International. IITA’s PEDUNE project is having impact in this area. These complement the traditional national extension programs where these are relatively strong, and take their place where they are very weak or non-existent.

11. Existing cowpea markets in Africa will be able to bear substantial increases in cowpea production. Cowpea demand is quite elastic in important areas of Africa such as Nigeria, the largest cowpea-producing and -consuming nation in Africa.

PREAMBLE – Cowpeas are an important food source for about 200 million people in Africa. Cowpea grain and leaves are rich in high quality protein, which has led to cowpea being referred to as "poor man's meat". In 1999, there were 8.8 million hectares of cowpea production in Africa, much of it grown by low-income women farmers. Africa's population is expanding more rapidly than its food production capacity. In the drier areas of West and Central Africa where cowpea is widely grown, food production is falling seriously behind population growth. For example millet and sorghum production estimates from International Food Policy Research Institute (IFPRI) show increases during the period 1990-1997 of only 1.1% annually, while population grew at almost 3 percent annually. It is estimated that less than 5% of the required increased food production can come from area expansion, while about 10% is expected to come from increased irrigation. Therefore, approximately 80% of the food required in the coming years will have to come from increased productivity per unit area of land. Urban populations in Africa are expanding particularly rapidly and are increasingly dependent on cowpea as a low-cost, nutritious, high-protein food. Also, more and more farmers see cowpea as a potential source of needed cash income. However, numerous biotic and abiotic constraints block the way to increases in cowpea production and to the expansion of the cowpea sector. One proven approach to increasing production is to improve the genetic make-up of cowpea cultivars.

Accordingly, an international group of scientists and stakeholders met in Dakar, Senegal, January 8-12, 2001, to develop a long-term general strategy as well as tactics for the genetic improvement of cowpea. The group's intent and hope is to increase the availability of affordable cowpea grain as food, as well as increase producer incomes and promote the environmental benefits of cowpea production.

The potential of cowpea is limited by numerous factors, but field and storage insect pests are the most severe constraints. Conventional breeding has made some progress toward developing and deploying insect-resistant cultivars, but the genome of cowpea lacks adequate sources of resistance for certain insect pests, including pod borers, weevils, pod bugs and thrips. Molecular biology offers new tools to introduce novel insect resistance traits that will help solve this otherwise intractable problem. These new traits will be introgressed into cowpea as part of traditional breeding programs.

Participants at the Dakar conference included cowpea breeders, integrated pest management (IPM) specialists, food scientists, economists, intellectual property experts, policy analysts, research administrators, as well as molecular biologists. There were scientists from nine African countries (i.e., Zimbabwe, South Africa, Nigeria, Senegal, Burkina Faso, Ghana, Mali, Benin, and Kenya), as well as from several universities, the private sector seed industry, and non-governmental and donor organizations from Africa, Australia, North America and Europe. Scientists participated from the International Institute for Tropical Agriculture (IITA), the United States Agency for International Development (USAID)-funded Bean/Cowpea Collaborative Research Support Program (CRSP), and the United

Nations Food and Agriculture (FAO) Sub-regional Office for Southern & Eastern Africa. Local support was provided by the Senegalese Institute for Agricultural Research (ISRA), which hosted the conference.

Cowpea is seen as a minor crop by large multi-national seed companies. Since cowpea is mainly produced by poor farmers in Africa, it is unlikely that these companies will invest in the development of insect-resistant varieties. The Dakar group sought to develop an alternative approach to improve cowpea using the tools of molecular biology, with the long-term aim of putting new varieties into the hands of farmers through African private sector involvement.

FINAL RESOLUTIONS OF THE MEETING

After five days of deliberation the group approved the following resolutions:

1) A coordinated international effort must be undertaken to bring new and beneficial traits into cowpea using the tools of molecular biology to address production constraints that cannot be dealt with by other means.

2) The effort must take a comprehensive view of the constraints in the proper regulatory framework for each country. These include environmental and food safety, policy, economics, seed systems, and intellectual property constraints.

3) The molecular biology tools to be applied should include:
   - Marker-assisted selection and genetic mapping
   - molecular genetic transformation

4) The new genetic tools should be integrated into traditional breeding programs to ensure development of varieties which are welcomed by African farmers and consumers.

5) The ultimate beneficiaries of this effort should be the impoverished farmers and consumers in Sub-Saharan Africa.

6) To ensure a comprehensive approach it is imperative that an effective coordination of all activities be provided by a steering committee comprised of specialists in the areas of genetic transformation, marker-assisted selection, environmental and food safety, economics, breeding, policy, public information, and intellectual property. This committee will be co-chaired by an African scientist and a scientist from one of the industrialized countries involved.

NGICA

Our community decided on the name "NGICA" – Network for the Genetic Improvement of Cowpea for Africa. Members of NGICA represent a spectrum of scientists, administrators, business people, non-governmental organizations, and individuals committed to the genetic improvement of cowpea and the eventual increased food production for sub-Saharan Africa.

The NGICA Steering Committee

The following individuals were chosen as members of a steering committee to guide NGICA as it develops initiatives and funding to genetically improve cowpea and increase food production:

Idah Sithole-Niang, University of Zimbabwe, Harare, Co-Chair
Larry Murdock, Purdue University, West Lafayette, IN, USA, Co-Chair
Eugenia Barros, CSIR-Bio/Chemtek, Pretoria, South Africa
Frederick Erbisch, Michigan State University, East Lansing, MI, USA
Russell Freed, Michigan State University, East Lansing, MI, USA
T.J. Higgins, CSIRO Plant Industry, Canberra, Australia
J.E. Huesing, Monsanto Corporation, Chesterfield, MO, USA
Louis Jackai, Tuskegee University, Tuskegee, Alabama, USA
Laurie W. Kitch, FAO Southern and Eastern Africa Office, Harare, Zimbabwe
Muffy Koch, Innovation Biotechnology, Midrand, South Africa
Jess Lowenberg-DeBoer, Purdue University, West Lafayette, IN, USA
Doug Maxwell, University of Wisconsin, Madison, WI, USA
Barry McCarter, Seed Co Ltd., Westgate, Zimbabwe
Johnson Olufowote, World Vision International, Accra, Ghana
Rob Paarlberg, Wellesley College, Wellesley, MA, USA
A.B. Salifu, Sahelian Agriculture Research Institute, Tamale, Ghana
B.B. Singh, IITA Kano Substation, Kano, Nigeria
Michael Timko, University of Virginia, Charlottesville, VA, USA

THE NGICA PROJECT FLOWCHART

The attached flowchart seeks to identify the major activities and tasks that must be undertaken and accomplished if (1) genetic improvements to cowpea are to be made using the tools of molecular biology and (2) these biotechnology products are to be eventually brought to the hands of ordinary cowpea growers and consumers in Africa. Links between various activities are also shown on the chart, and there is an attempt to roughly indicate the time-relationships. The flowchart was developed with inputs from many NGICAns, and is a working hypothesis. As an hypothesis, it will undoubtedly be modified and adjusted upon further study and experience. Still, as we prepared the working flowchart, several facts, lessons, sub-hypotheses, or ideas emerged.

- The use of marker-assisted tools or genetic transformation of cowpea to produce enhanced cowpea germplasm is a small part of a greater, long-term task.
- Many activities that are vital for eventual impact must be anticipated, and work begun in a timely manner; certain tasks may take years to complete.
- Intellectual property-related issues (acquisition, management, liability, freedom-to-operate) need to be addressed early on, and not later.
- Any one public institution or industry is inadequate to do the job of getting the benefits of an investment in biotechnology. A community effort of stakeholders is essential and must be, fostered, and sustained.
- Substantive involvement of Africans is essential in the planning, developing, testing, and disseminating of cowpea-related products of biotechnology.
- Initiatives to use biotechnology for cowpea improvement are just part of a broader effort to use molecular techniques for crop improvement
- Implementation of transgenic cowpeas will first occur in a single African nation. Likely early-adopter candidate nations should be identified early to involve national people in the project as well as help develop infrastructure.
- Eventual dissemination of transgenic cowpeas with insect resistance or other improved traits will have to be sustainable, or else the effort will be a failure.
- Biotechnology for cowpea improvement must not be pursued in isolation; it’s products should be bundled together with other cowpea technology products.

OUTPUT
OF
WORKING GROUPS

Group 1

Cowpea Transformation and Useful Genes

Chairpersons: Idah Sithole-Niang and Doug Maxwell

Participants: Richard Allison, Ray Bressan, T.J. Higgins, Joseph Huesing, Jesse Machuka,

Transformation

Constraint: We lack a robust, efficient, reproducible and reliable method for transformation of cowpea. This prevents us from bringing new sources of useful genes into this important crop. Additionally, there is no genetic resistance for the legume pod borer, *Maruca testulais*.

Outline of Proposal:

1. Source of Bt toxin genes (cloned and codon modified for plant use)
   (The most likely classes to be effective against *Maruca* are Cry 1 and Cry 2)
    a. Monsanto
    b. Bill Moore (Auburn University)
    c. The Rockefeller Foundation
    d. Other academic sources (Canadian scientists)

2. Bioassay for Bt toxin effective against *Maruca testulais*
   In this assay, purified Bt protein is tested for its effectiveness against various Maruca biotypes.

3. Vector Construction
    a. IP evaluation with consultant
    b. Biosafety evaluation of construct
    c. Separate vectors will be prepared that are specific to the two transformation systems to be used. Different vector backbones will be required for the different transformation systems.

4. Gene transformation – Presently cowpea has not been transformed. There are several transformation methods that may be adapted to the cowpea. Two different methods have been chosen to ensure that transformants will be produced. Agrobacterium transformation is a labor-intensive approach that has been yielded soybean and field pea transformants at a low but dependable efficiency. Electrotransformation is a new experimental system that shows great promise of providing transformants at a higher efficiency than the Agrobacterium method without the added burden of selectable markers. Transformation work will proceed simultaneously in two different laboratories practicing the techniques and African scientists will participate and become familiar with the details of the techniques.

a. Agrobacterium transformation – Requirements:
    1. Twin T-DNA transformation backbone
       (This enables removal of the selectable marker through breeding,
       IP issue for twin T-DNA transformation – Japan Tobacco)
    2. Promoter 35S – Monsanto (expression of all tissues)
    3. Alternative promoter Super Promoter – Amoco (expression of all tissues)
    4. Transcriptional stop 3'UTR nos
    5. Potential selectable markers for herbicide resistance
        i. Bar – Aventis
        ii. Glyphostate – Monsanto

b. Electrotransformation
    1. Promoter 35S – Monsanto (expression in all tissues)
    2. Alternative – Super promoter – Amoco (expression in all tissues)
    3. Transcriptional stop 3'UTR nos

5. Lines for transformation
   Select 20 best lines and transfer lines to Australia and US
   (Seeds for Australia must pass through quarantine)

6. Screen lines for regeneration in tissue culture, Agrobacterium transformation, and sensitivity to electrical current, electrotransformation.

7. Development of transformation technique
    a. Agrobacterium method has been used for field peas in Australia
       Screen TO plants with PCR for presence of gene and with serology for Bt toxin gene expression.
    b. Electrotransformation system requires PCR and Southern selection at T1 stage.
8. Production of T1 seed and screen for homozygous lines for Bt levels.

9. Evaluation of transgenic cowpeas (USA)
    a. Insect bioassay – greenhouse evaluation of transformants to determine effectiveness of each transformed line against *Maruca*
    b. Molecular analysis for:
        i. Number of insertion sites
        ii. DNA flanking sequences.

10. Evaluations
    a. Toxicity assays in animal feeding experiments in US (may not be required if gene previously evaluated for toxicity). Under current African biosafety policy this screen will be required for each transformed line.
    b. Field evaluation in Africa (IITA)

11. Breeding program for incorporation into elite lines and field evaluation over several generations

12. Biosafety

Major issues for consideration by other groups:

1. Cost benefit analysis
2. Freedom to operate
3. Public acceptance
4. Regulatory system in major cities (environmental and health safety)
5. Insect resistance and crop management plans
6. Transformation of lines with unique and visible phenotype
7. Ownership of IP transgenic cowpea

Cowpea Transformation and
Useful Genes Budget

Bioassays of Toxins USA (Year 1)	$50,000
Gene construction (USA) (Year .5 – 1.5)	$70,000
Transformation –	
Australia (Year 1.5 – 6.0)	$145,000/year
USA (Year 1.5 – 3.0)	$80,000 - $100,000/year
Legal Costs	$50,000
Quarantine Costs Australia (Year 1)	$5,000
Bioassay of Plants USA?	$50,000
Field Trials Africa (2 Years)	$20,000/year
Animal Feeding Trials USA	$50,000
Back-crossing Africa (3 years)	$15,000
Travel	$30,000

Transformation Group Time Line						
Activity	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Sources of Bt & Marker Gene	XXX					
Bioassay	XXX					
Gene Construction		XXX				
Transformation		XXX	XXXXXX	XXXXXX		
Seed Transfer	XXX					
Quarantine	XXX					
Screen Lines for Regeneration		XXX				
Screen T0				XXX	XXXXXX	XXXXXX
Screen T1					XXXXXX	XXXXXX
Bioassay					XXX	XXXXXX
Field Trials					XXX	XXXXXX
Toxicity						XXXXXX
Breeding						XXX
Back Cross						XXX
Monitoring						XXX

Group 2

Policy Framework, Intellectual Property and Regulation

Chairpersons: Rob Paarlberg and Fred Erbisch

Participants: Mamadou Gueye, Laurie Kitch, Mywish Maredia, Mamadou Khouma

Lifting Policy Constraints

The potential of genetically improved cowpea to improve the lives of small low-resource farmers in Africa will depend significantly upon the presence of an enabling policy environment, particularly within the African countries employing the technology. Existing policy environments in Africa are frequently less than ideal for the uptake of productive farm technologies. In the case of GM technologies, the international policy environment, including the Intellectual Property Rights (IPR) environment, can be difficult as well. In this regard transgenic technologies could encounter several specific constraints. This project will address three policy constraints in particular:

- *Intellectual Property Rights Constraints* that will be faced by scientists designing transformed cowpea varieties and by the African national agricultural research systems incorporating GM cowpeas into their breeding programs.

- *Political Acceptance Constraints* that might grow out of any uncertainties within African governments regarding obligations that have been undertaken in various international for a such as the Convention on Biological Diversity, World Trade Organization (WTO), and Codex.

- *Administrative Capacity Constraints* within African governments in the specific area of biosafety policy implementation

A. IPR Constraints and Proposed Responses

This project can expect to encounter IPR constraints at three distinct stages, and a separate response is proposed for each stage.

1. Design of transformation process. At this first stage, scientists designing transformation processes for cowpea will have to be aware of the differing IPR encumbrances implied by the various approaches under consideration. If a technology is designed which incorporates too many separate patents held by too many separate institutions, the task of making that technology available at an affordable price to farmers in Africa would become needlessly expensive and complicated.

   In order to lift this constraint we propose to commission the services of an IPR consultant to establish early contact with the transformation team to advise on the

IPR implications of various scientific strategies. This consultant will review early planning proposals from the transformation team, conduct IP audits of the materials and processes proposed for use, review existing agreements regarding transfer of such materials and processes. As scientific progress is made, this IP consultant will approach patent holders seeking agreements for royalty-free licensing of the technologies in question when incorporated into cowpea for use by national agricultural research systems within Africa. The estimated cost of these services will be $10,000 per year for at least the first three years of the project, for a total of at least $30,000.

2. Information sharing with African National Agricultural Research Systems (NARS). Even if permission for royalty free use is granted by all patent holders, a second constraint can nonetheless arise at the acceptance end. African governments will want a number of questions regarding IPR answered before they allow breeders within their national systems to backcross into national germplasm transgenic varieties of cowpea that carry foreign-owned IPRs. They will want to know if the new varieties created in this fashion will also carry foreign-owned IPRs, and if so what restrictions could be placed on their subsequent use, within Africa or elsewhere, by the national system. They will want to know who will own IPRs for any new discoveries generated within their own systems by the project. They will want to know the implications of working with IPR-protected plant materials inside their national systems if their own government does not yet have any patent or plant variety protection laws that apply to plants. They will have questions about the solutions to these questions and problems that have been worked out by other African governments in the case of similar public sector Bt crop initiatives, such as the Insect Resistant Maize for Africa (IRMA) project being managed by the Centro International de Mejoramiento de Maiz y Trigo (CIMMYT) and Kenya Agricultural Research Institute (KARI) in Kenya.

    In order to lift this constraint we propose commissioning two authors to research and produce a plain-language primer on the general IPR implications of the proposed transfer of Bt cowpea into Africa. At least one of these researchers should be an African, ideally an IPR officer within the NARS that is expected to supply the local breeding program complement to this project. This primer should be published in English and French, and the authors should make themselves available to present their work through seminars to NARS and other officials in Africa. Consideration should be given to publishing and promoting this primer through Food and Agricultural Organization (FAO), or International Service for National Agricultural Research (ISNAR), or Strategic Alliance for Biotechnology Research in African Development (SABRAD). Estimated budget cost to this project is $75,000.

3. Consulting Services to NARS. When the time comes for transformed cowpea materials to be transferred into the hands of African NARS, specific IPR contracts will have to be negotiated both for research use and commercial use with the patent holders, based on understandings earlier reached through the

transformation team. These NARS may then subsequently be required to negotiate and sign IPR licensing agreements with private seed distributors. In such circumstances the African NARS in question will benefit from the consulting services of an IPR expert. The project will provide these services at an estimated cost of $30,000 per NARS.

B. International Policy Obligation Constraints

African governments may hesitate to import or begin planting GM cowpeas until they have been reassured that these actions are compatible with the international obligations they have undertaken or are being asked to undertake in several related international biosafety, trade, and food safety settings, including the Convention on Biological Diversity (CBD), the World Trade Organization (WTO), and the Codex Alimentarius Commission.

1. CBD: In January 2000 the Conference of Parties within the Convention on Biological Diversity reached agreement on a new Biosafety Protocol designed specifically to govern the transboundary movement of Living Modified Organisms (LMOs). A broad coalition of African governments (negotiating as a so-called "like minded group") emerged as strong supporters of this Protocol, and unless the GM cowpea project planned here can be presented as compatible with this Protocol it may be blocked by government authorities in Africa. The Protocol was negotiated by environment ministers and is designed to give importing states the right and the opportunity to block imports of LMOs (for example, GM cowpeas) on a precautionary basis in order to protect biological safety, even if the scientific evidence of risk is uncertain. While the Protocol allows importing states to take this highly precautionary approach, it does not require that they do so. Nonetheless, environment ministries and some NGOs in Africa can be expected to invoke the Protocol possibly in objection to the import of GM cowpea materials.

2. WTO: The World Trade Organization, on the other hand, discourages the use of purely precautionary import restrictions. The Sanitary and Phytosanitary (SPS) agreement in WTO permits governments to halt imports that may be suspected as environmental risks, but only on a temporarily and "provisional" basis while scientific evidence of risk is being sought. African governments will want to know how to weigh this SPS agreement within WTO against the Biosafety Protocol mentioned above. In the IPR area they will also want to know the details of the Trade-related Aspects of Intellectual Property Rights (TRIPS) agreement within WTO, which requires all developing countries to have plant variety protection laws in place by 2006.

3. Codex: Within the Codex Alimentarius Commission in Rome a Working Group is currently meeting to consider the possible need for special food

safety and labeling rules related to GM foods. Health Ministries and Food Industry authorities within African governments may want to know the outcome of these deliberations prior to introducing GM cowpeas into their national food systems.

In order to lift these constraints this project will commission and publish (in English and French) a technically accurate and up to date summary of the relevant international obligations African governments must consider when importing or planting GM crops. African governments will learn from such a review that there are in fact no international obligations currently at odds with the import or planting of GM crops such as cowpea. This report should also be co-authored with at least one of the authors again being an African. The anticipated budget cost of researching, drafting, publishing, and translating this report is $75,000.

C. Biosafety Administrative Capacity Constraints

In many African governments national biosafety regulations have not yet been drafted, or they have been drafted but not yet approved, or they have been drafted and approved but not yet implemented. Elsewhere in this project (the Biosafety working group) proposals are being made to leverage international resources to strengthen the training of national biosafety regulators in the African governments that will be in a position to produce or import GM cowpeas. In addition to training deficits in the this area, the newly formed National Biosafety Committees (NBCs) of many governments in West Africa lack the basic technical and administrative capacity to do their important job (reviewing applications for GM materials imports, field trials, and release) in a self-confident and timely fashion. Many of these committees have only a token secretariat, no database, and little or no Internet access. This project proposes to lighten such constraints in the countries where GM cowpeas are to be introduced by taking three steps:

1. In the one or two countries where GM cowpeas are first to be introduced, an audit of the administrative capacities of national biosafety committees will be conducted, and following that audit the project will leverage some of its own funds in partnership with other international donors (perhaps UNEP, or FAO, or a bilateral donor such as USAID) to ensure full time internet access to the secretariat of the committee. Estimated budget cost: $50,000.

2. In order for national biosafety committees to operate with confidence, and with full information regarding the parallel actions of other biosafety committees in the region, they must have access to the current status of GM crop technology applications and approvals in those other countries in the region. There is currently no single place for NBC's to go to learn what their counterparts have been doing. This project proposes to hire a part-time contractor to gather the information needed to build and maintain for two years a website providing the current status of biosafety applications in all the African countries where biosafety committees have been receiving and

considering such applications. Alternatively, this updated inventory of approvals could be posted on one of the other websites being proposed in this project. Maintenance of this web posting and inventory process would then be handed over to the NBC's themselves. Estimated budget cost: $75,000.

3. Finally, to ensure a smooth and timely functioning of the biosafety approval process in the African countries in questions, consulting services regarding applications for biosafety approval should be provided to the NARS that will be seeking either to import or field test or release GM cowpea varieties. Individuals with experience in biosafety approvals elsewhere in Africa will be retained to provide the relevant NARS with information and advice on cowpea applications. Estimated budget cost: $30,000.

Budget Summary

1. IPR Constraints

IP consulting services for scientists $30,000
Commission, translate, and publish
IPR primer for African governments........$75,000
IP consulting services for NARS...................$30,000

2. International Policy Obligation Constraints

Commission, research, translate, and
Publish technical summary for
African governments................................$75,000

3. Biosafety Administration Capacity Building

Funds to leverage Internet access for
NBC..$50,000
Research inventory of biosafety approvals
In Africa then build and operate website for two
years..$75,000
Biosafety approval application consulting
Services for NARS...................................$30,000

Total..$365,000

Group 3

Genetic Mapping and Tools for Breeders

Chairpersons: Mike Timko and Eugenia Barros

Participant: Diaga Diouf

Summary

In order to assist in the rapid development of cowpea varieties with phenotypes optimized for maximum productivity under biotic and abiotic constraints in various regions of Africa, molecular markers associated with various major cowpea pest and disease resistance genes, genes conferring drought resistance and photoperiod control will be developed and these markers will be converted into tools for marker-assisted selection and breeding. Working through international, regional, and local laboratories, marker development and use will be interfaced with national breeding programs. Training in use of molecular tools and marker-assisted selection will be provided to build local capacity. To facilitate marker development, this project further aims to develop a saturated and multifunctional molecular marker map of cowpea. This map will serve several different purposes ranging from facilitating the resolution of complex genetic traits into their single gene components, to allowing efficient gene introgression into commercial cultivars by marker-assisted breeding, and positional cloning of any cowpea gene of interest. To validate the utility of the map, at least one gene for each trait will be isolated and characterized.

To exploit the map information to its full extent for molecular breeding, a "tool kit" consisting of framework markers uniquely defined by their genetic and physical location, electrophoretic mobility, and the sequence of the oligonucleotide primers and/or restriction enzymes used will be generated, and a supporting database showing the molecular markers locations within the cowpea genome will be placed on a World Wide Web (www) site. These tools will allow researchers worldwide to easily locate traits of interest and compare data (map-positions) among genotypes, cultivars, and wild accession lines. To further facilitate use of the framework molecular markers for mapping and comparison of information among different cowpea genotypes, DNA samples of the reference genotypes for mapping parents will be generated and made available upon request to the researchers. Finally, an ordered library of Bacterial Artificial Chromosomes (BAC) fragments will be maintained allowing independent investigators to easily identify contigs of interest for subsequent cloning and characterization studies.

Research Constraints and Specific Research Objectives

The lack of a rationale genome project for cowpea, leading to the development of new, reliable PCR based markers for screening and selecting germplasm for crop improvement, is likely to be one of the key hindrances to development of cowpea as a premier foodstuff and economic crop.

We know from the tremendous strides made in other crop species, such as rice, corn, tomato, and soybean, that the direct application of biotechnological tools including marker assisted selection and directed gene cloning and manipulation can lead to rapid improvement of crop productivity and value over a short period of time. By comparison to other grain and seed crops of similar agronomic, social and economic value, biotechnological based improvement of cowpea is still in its infancy. At the present time, the framework for a high-resolution genetic map is in place, with markers currently covering approximately 2600 cm of the genome. Several important agronomic and disease resistance traits have been placed on the map, however, the total number and variety of traits mapped is very small.

The rapidity by which some disease pathogens are able to generate new virulent pathotypes limits the commercial life of many hybrids to only several years. The employment of hybrids with monogenic or in some cases even oligogenic resistance has contributed to the problem and escalated the need for resistance gene pyramiding. This can be a long and arduous process using conventional approaches. Molecular aided selection can speed the process and in some cases help eliminate unwanted defeated characteristics. At the present time, the number of molecular markers directly associated with particular agronomic and disease/pest resistance traits is small and even more limited are the number of markers that have been converted into diagnostic tools for use in marker assisted selection and breeding strategies. The lack of such tools is a clear constraint on rapid cowpea improvement

In cases where gene mapping is being done, there is not baseline for comparison of work among research groups or mechanism of easy information exchange about map locations and available molecular resources. Currently, no physical map of the cowpea genome is available and to our knowledge no large-scale gene expression (e.g., EST) or sequence analysis projects have been undertaken. While foundry studies are underway to define "framework" molecular markers covering the cowpea genome that will allow comparisons among genotypes, cultivars, and wild-accessions, these technologies are not developed to a sufficient extent to be useful to the broad cowpea community.

To alleviate this constraint, we propose a plan of action which encompasses five major objectives. These objectives are as follows:

(1) Identification of support centers within Africa that will serve as the site for the development of markers for marker-assisted selection, provide service to local breeders in using the markers for screening and selection of germplasm for use in breeding programs, and as training sites to extend the use of the technology to more localized "programs" with appropriate capacities. At this time we envision that laboratories such as those at IITA (international), CERAAS (regional - west and central Africa), and CSIR (south and east Africa) with already established research facilities, support personnel, and expertise would be the logical choices for participation in development of framework markers, use of these markers, and implementation of marker assisted selection within Africa. A role of the centers and local programs will be the development of specific lines containing multiple traits to streamline map improvement, marker development and gene isolation.

(2) To improve on the current genetic map of cowpea by adding additional molecular, biochemical, physiological, and morphological markers which will provide a ready source of tools for the development of markers for assisted selection;

(3) To establish a reference marker tool kit and an online database of molecular markers that will allow researchers worldwide to easily locate agronomic and pest/disease resistance traits on the cowpea genetic map and identification of candidate molecular markers for subsequent development of markers for assisted breeding. These markers will also allow researchers to easily compare genotypes and cultivars from different locations and lead to the development of additional markers based upon their own research programs;

(4) To identify specific sets of molecular markers linked to traits of agronomic importance identified by breeders located in "hot spots" within Africa. For example, using the marker tool kit and online information researchers at appropriate regional centers will develop markers for selected traits of interest (insect pests, drought tolerance, fungal and bacterial disease resistance and resistance to parasitic plants) known to constrain cowpea productivity in Africa. The goal is to move as rapidly as possible to identify markers linked to traits of interest and to convert these markers into easily applied, accessible tools for use in rationale marker-assisted breeding and selection programs aimed at rapid delivery of new, improved, and grower acceptable cultivars.

(5) To generate a physical map of the cowpea genome using libraries of bacterial artificial chromosomes (BACs) and integrate it with genetic map for cultivated cowpea, in order to allow for the rapid identification, cloning and characterization of genes of agronomic interest and importance.

Project Justification

The main objective of this project is to provide tools for the improvement of cowpea productivity in the near term and to establish the foundation for future efforts on genetic manipulation and advancement of the crop in the future. To meet this goal it is essential to construct a high density map of the cowpea genome that can serve as the basis for the speedy development of tools for molecular breeding of plants with improved characteristics for the most pressing biotic and abiotic constraints on productivity (i.e., insect damage, disease, drought, etc.). The construction of a high-density map is not an unprecedented approach to study an organism which is of great agricultural importance but for which it is likely that the genome will not be fully sequenced in the foreseeable future. Therefore, using this strategy we will develop capabilities, in which potentially every gene of interest can be cloned by means of the map. Parallel to the genetic mapping objective of this project, a cowpea bacterial artificial chromosome libraries will be developed. As noted above, with the aimed marker density, a coverage of at least 1 mapped marker per cowpea-BAC clone should be achieved. The BAC libraries contain, among others, a number of cowpea disease and pest resistance genes, in addition to other genes of agricultural importance. The use of the high-density genome marker catalogue in concert with the BAC libraries potentially provides a one-step approach to identify additional markers as well as putative homologues of the gene of interest. As such it can be considered as being an alternative for a genome-sequencing project.

Plan for Future Research

The project has been subdivided into the following experimental tasks:

(1) Identification of support centers within Africa that will serve as the site for the development of appropriate mapping populations, markers for marker-assisted selection, to provide service to local breeders in using the markers for screening and selection of germplasm for use in breeding programs, and to function as training sites to extend the use of the technology to more localized "programs" with appropriate capacities.

(2) Identification of molecular markers associated with key disease and pest resistance traits and plant quality traits of economic importance and their integration into breeding programs via regional centers;

(3) Construction of a reference collection of common molecular (AFLP, RAPD, IDP) markers, construction of a tool kit for breeders to facilitate location of genes for key traits on the map, and establishment of an on line catalogue for gene placement, identification of potential markers, and genotype comparison.

(4) Improvement of the current genetic map (i.e., construction of an ultra-high density map of cowpea) to facilitate marker identification and gene cloning.

(5) Initiation of studies aimed at development of a physical map for cowpea and its integration with the genetic map.

Benefits

A high-resolution genetic map and corresponding physical map for cowpea can serve various purposes in basic genetic studies and applied breeding programs. The genomic position of qualitative as well as quantitative traits can be determined more efficiently and more accurately than with current genetic maps, which will enhance the possibilities to identify and select genotypes with a specific combination of traits.

Numerous single gene and quantitative trait loci have already been placed on the cowpea map. As the of use molecular-marker analysis for gene mapping becomes more widespread in the cowpea community, the number and variety of traits placed on the map will increase. A large number of populations segregating disease and pest resistance, drought tolerance, growth and yield parameters and other characteristics, have already been developed through the effort of breeders which can be used in mapping activities. Coordination of efforts between laboratories to exploit these resources is important to ensure rapid future progress.

In addition, it will be possible to clone and characterize genes of interest via 'chromosome landing', which will allow the rapid movement of genes among cultivars or the transfer of novel genes from related wild species to commercial cultivars. In this way, crop improvement can be accomplished with regard to disease resistance and quality aspects like seed protein composition and quality, growth characteristics, photoperiod response, and disease and pest resistance.

Who will do it?

There is little doubt that to successfully conduct these studies we will require the cooperation of the cowpea community at large. We envision the following division of labor for the activities outlined above to be as follows:

The Steering Committee with input from the Working Groups and cowpea community will be responsible for identifying the regional/local research centers that will serve as the focal point for the initial work on marker development and implementation in Africa.

We have identified the IITA (Ibadan), CERAAS (Senegal), and CSIR (South Africa) as the initial participant centers and leave open the identification of local centers to the community.

The development of populations for mapping of genetic traits is already underway in many breeding programs and studies are underway to identify markers associated with these traits. This work will continue and be integrated into the larger program aimed at map development as the markers become available. Development of framework markers, the “tool-kit” for breeders, and the on-line catalogue will be done collaboratively between the group at University of Virginia and the regional centers. The identification and testing of framework markers and appropriateness of techniques (protocols) will be empirically determined by information exchange between the groups. The development of markers, conversion of markers to selection tools, and use of molecular markers in selected breeding programs and germplasm characterization will be conducted at the regional/local centers. Markers identified at the centers will be placed on the map using criteria defined under mapping group guidelines. Map improvement, development of the tool-kit and related activities, and studies aimed at physical mapping will be centered at the University of Virginia with cooperation for generalized mapping contributed by the individual groups. The development of BAC libraries and their testing will be done by University of Virginia and CSIR.

Time frame and Budget

(1) Problem Identification and Development of Segregating Populations (African National Breeding Programs and Regional/International Laboratories)

Population development will take place within the national breeding programs and/or at regional/international laboratories and populations identified by the individual programs will be supplied to the regional centers for marker development. Some segregating populations are already developed and others are in progress. Available populations segregating for *Striga* resistance, drought tolerance, and insect resistance are to be used in the first year. No cost to the program.

(2) Marker Development at Centers

Using selected advanced populations, markers will be developed for each trait. We estimate that the time frame for development of a marker or markers linked to a specific trait is approximately six months to two years. This includes the time for conversion of linked markers to SCARs, CAPs, or other forms easily applied in marker-assisted breeding. We estimate the cost of generating a marker set to be as follows: $10, - 15,000 per year in reagent costs and $35,000 per year in labor (one full-time student or technician) including health benefits. The estimated total cost is $50,000 per year for each trait. There will be some variation in this amount and it is possible that streamlining can reduce costs in subsequent years.

The traits identified by the breeders as candidates for marker development are: bacterial blight, Striga resistance, drought tolerance, photosensitivity and aphid resistance.

We propose that marker development will take place at each of the three identified African centers and in the lab at UVA with the participation determined by expertise and interest with respect to the needs of the respective programs. The first round of markers should be ready to transfer to the field for integration within two years. As new populations are developed, additional projects will be initiated with appropriate laboratories and new budgets requested. We estimate that each center will be responsible for marker development of two traits. The estimated cost will thus be $100,000 per year per center.

(3) Training and Technology Transfer to Local Laboratories

Each of the centers involved in marker development will provide training for students and researchers to allow the capacity for marker development and marker assisted selection to be integrated into local laboratories. Fellowships and training stipends of between $10,000 and $25,000 per student will be provided depending on the location and cost. Selection of trainees will be done by national programs and will be consistent with their needs for capacity development.

(4) Map-improvement (UVA), Tool-kit/framework marker development (UVA, CSIR, CERASS) and Physical Mapping (UVA and CSIR level).

Map improvement, development of the framework tool-kit for use by local programs and physical mapping will be carried out at the University of Virginia with input from the African laboratories.

UVA component - two research scientists, two technicians (years 1-5)
CSIR component (BAC library contributor) - 1research scientist, 1 technician

Locally at UVA, two research scientists will be involved in this project and full-time salary and benefits are requested for them. Dr. Chunxiao Jiang has been working on various aspects of gene mapping in plants for several years. He will be responsible for high resolution mapping of the cowpea genome and BAC library construction. He brings a wealth of experience in mapping to the project. Dr. Bhavani Gowda has been involved in the RGA characterization and mapping in cowpea and in the initial development of the cowpea map. He will be responsible for preparation of framework markers and for the conversion of Striga markers to selection tools.

Because of the labor-intensive aspects of the project, I am requesting salary and benefits for two full-time technical staff at the level of Laboratory Specialist Senior. One Laboratory Specialist Senior will work with Dr. Jiang on genome map improvement and BAC library construction. The second requested Laboratory Specialist will assist Dr. Gowda in the marker conversion. He/She will also devote 20% of their time to maintenance of the plant material required for this analysis.

A yearly request is made to defray the cost of purchasing the general biochemical reagent and supplies (e.g., agar, agarose,), specialized molecular biologicals (e.g., restriction endonucleases, DNA polymerases, Taq Polymerases, etc.), small equipment items (e.g., pipettemen, etc.), and disposable glassware and plastics necessary to conduct the proposed experiments. The amount of our request for these items ($50,000) is based upon our average expenditures per person per year during the past three years.

We propose to generate a BAC library of at least 20,000 independent clones. We estimate the initial cost of library preparation to be approximately $50,000 during the first year. This cost includes the purchase of pIndigoBAC-5 kits, TransforMax EC100 Electrocompetent Cells, and the reagents and tools necessary for picking individual clones, clone characterization and placement into microtitre plates for storage and future analysis. The costs for BAC characterization, end clone sequencing, etc. are added in to the yearly supplies request. The Biomolecular Research Facility at the University of Virginia Health Sciences Center (Dr. Jay W. Fox, Professor and Director) will help us in preparing the BAC arrays and assist in image analysis following hybridization. A conservative cost estimate for preparation of clone arrays based upon several (3-4 filters is approximately $1000).

General Molecular Biology Reagents	$ 50,000
BAC library construction materials	$ 50,000 (Year 1 only)
Preparation of BAC Arrays	$ 1,000 (Year 2)

Funds are requested to allow the Senior Scientists and Principal Investigator to travel twice a year to Africa in order to discuss results and plan experiments accordingly with the consultants.

Independently, BAC library construction is also being carried out using DNA from a drought tolerant cultivar at CSIR. The work is just at the initial stages and Dr. Jiang (UVA) will travel to CSIR to assist in getting this initiative underway. In discussing the wisdom of creating more than one library with various scientists, there is clear value in working in different genotype. Costs for BAC construction at CSIR and costs for salaries for the persons who will conduct these studies (identified at a later time). An estimated cost for CSIR component is $75,000 per year.

(5) Testing of Framework markers at CSIR, CERASS, and IITA

To validate the efficacy of the "Tool Kit" for rapid gene location and marker identification being developed by scientists at UVA, funds ($15,000 per year) are requested to defray the costs of marker testing of segregating populations and in germplasm genotyping studies during years 1 and 2. After two years we should have developed sufficient framework markers and to have progressed on map saturation to have a well established protocol.

Year 1: $45,000   Year 2: $45,000

Summary Budget

Marker (single trait) Development (Africa/US):
6-8 markers X $50,000/marker (Years1 - 2)

MAS costs (Africa):
Each year/marker (years 3-5) $5000/marker/year ($40,000)

Training Costs for MAS at Centers:
$10-25,000 per student/year/center (2 students)

Assist in tool kit development and verification testing at centers:
$15,000 per year per center (outside of US)

Travel Costs (For PIs, Senior Scientists, Student): $40,000

Map Development, tool kit development, protocols, physical mapping (years 1-5):

(UVA)	$375,000 per year
(CSIR)	$75,000 per year (BAC assistance)

Group 4

Food, Environment and Safety Issues and Strategy

Chairperson: Muffy Koch

Participants: Ousmane Ga, Larry Murdock, Dick Phillips, Yvonne Pinto, Lat Tounkara, Louis Jackai

Proposal to incorporate a biosafety strategy into the cowpea genetic improvement project

Key constraints to implementing a biosafety strategy for cowpea in West Africa include:

- A lack of information
- A lack of appropriate technology
- Low public awareness
- A lack of political will
- A lack of biosafety structures
- A lack of biosafety capacity in the region and
- A lack of biosafety information on cowpea and its genetic improvement(s).

The first five constraints will be dealt with by other initiatives in the larger cowpea genetic improvement project. Relieving the constraints of biosafety capacity and specific biosafety information for cowpea will be addressed by this proposal.

Priorities in dealing with constraints
Addressing the lack of biosafety capacity and the gaps in cowpea biosafety information are equally weighted. It is proposed to deal with them simultaneously.

Rationale and justification:

Providing biosafety capacity to scientists within the greater cowpea project will

- Ensure that development of genetically improved cowpea proceeds with a 'safety first' approach;
- Ensure that the most appropriate constructs are developed and used for the improvements;
- Help avoid an unintended introduction prior to full safety assessment;
- Enable the efficient movement of suitable improved cowpeas though the regulatory process;
- Bring the project into line with the Cartegena Protocol on Biosafety;
- Build confidence in the ability to assess safety; and
- Provide a resource pool of expertise available to national biosafety committees for review of applications to work with genetically improved crops in the future.

Once trained in biosafety risk assessment, management and communication, these scientists will be able to assist with risk assessment reviews of other genetically modified organisms.

Providing accurate biosafety data for cowpeas in general and the specific genetically improved crop, in particular, will

- enable the safe and responsible introduction of genetically improved cowpeas into the region,
- ensure that applications for work and release contain all the information required by national biosafety committees for approval of the proposed work, and
- generally expedite the regulatory approval processes needed for the development, testing and release of the genetically improved cowpea.

Workplan outline

Biosafety Workplan			
	Phase 1 (Laboratory)	**Phase 2 (Field trials)**	**Phase 3 (General release approval)**
Gene construct safety	No animal genes	Possibly remove or knock out marker genes	
	Preference for elements with regulatory approval		
	Check safety of elements: markers, extraneous DNA		
	Resistance management		
Environmental safety	Survey current status: what has been done; what is available; what gaps need to be filled.	Biodiversity impact: crop, insects, exudates.	Monitoring
	Research	Abiotic impact	Monitoring
	Gene flow – outcrossing and wild/exotic relatives	Gene flow, cont.	Monitoring
	Invasiveness	Invasiveness, cont.	Monitoring
	Weediness	Weediness, cont.	Monitoring
	Gene stability	Gene and trait stability	Monitoring
	Resistance management – model, baseline data over 3 years	Resistance management	Monitoring
		Monitor confinement conditions	

Food safety	Survey current status: what has been done; what is available; what gaps need to be filled, e.g. Toxicity, anti-nutritional compounds inherent in germplasm	Gene products and whole food: nutritional changes, digestion and digestion products, processing (food and feed) impact – fate of DNA and new proteins	
	Research to fill base line gaps		
Capacity building	Biosafety training for scientists	Biosafety for regulators	
	Database information collection on biosafety of cowpea and the constructs		

Time frame

	Phase 1 (Laboratory)	**Phase 2 (Field trials)**	**Phase 3 (Approval for general release)**
Biosafety component	2 years	3 years	3 months to 1 year
Total project estimate	Gene construct and transformation = 5 years	Field evaluation and breeding = 8 years	N/A

Budget

Biosafety Workplan Budget – An estimate			
Phase	**Activity**	**Costing**	**Estimate (US$)**
Gene constructs			
Phase 1 (Laboratory)	Biosafety review of constructs	40h @$40 Travel: 1 x national	1600 400
Phase 2 (Field trials)	Biosafety review of constructs in varieties identified for general release	40h @$40 Travel 1 x national	1600 400
Phase 3 (General release)	None		0
Environmental safety			
Phase 1 (Laboratory)	Survey current status: what has been done; what is available; what gaps need to be filled.	120h @ $20 Telecom, printing, stationery Travel x 1 trip	2400 180 4000

	Gene flow – outcrossing and wild/exotic relatives	(Already underway and budgeted for)	0
	Invasiveness	3 MSc students in 3 growing areas, 2 years Running costs Travel: 3 trips	15000 12000
	Weediness	3 MSc students in 3 growing areas, 2 years Running costs Travel: 3 trips	15000 12000
	Gene stability	(transformation group cost)	0
	Resistance management – model, baseline data over 3 years	1 PhD for 4 years Running costs	
Phase 2 (Field trials)	Biodiversity impact: crop, insects, exudates.	3 MSc students in 3 growing areas, 2 years Running costs Travel	15000 15000 12000
	Abiotic impact	2 MSc students, 1 trial location, 2 years Running costs Travel	10000 10000 8000
	Gene flow, cont.	(Already underway and budgeted for)	0
	Invasiveness, cont.	1 MSc student, 1 trial location, 2 years Running costs Travel	5000 5000 4000
	Weediness, cont.	1 MSc student, 1 trial location, 2 years Running costs Travel	5000 5000 4000
	Gene and trait stability	(breeders' cost)	0

	Resistance management		
	Monitor confinement conditions	1 MSc student, 1 trial location, 2 years Running costs Travel	5000 5000 4000
Phase 3 (General release)	Monitoring	3 MSc students in 3 growing areas, 2 years Running costs Travel	15000 15000 12000
Food safety			
Phase 1 (Laboratory)	Survey current status: what has been done; what is available; what gaps need to be filled, e.g. Toxicity, anti-nutritional compounds inherent in germplasm	120h @ $20 Telecom, printing, stationery Travel x 1 trip	2400 180 4000
	Research to fill base line gaps	To be costed once survey has been completed	12000
Phase 2 (Field trials)	Gene products and whole food: nutritional changes, digestion and digestion products, processing (food and feed) impact – fate of DNA and new proteins	To cost before start of Phase 2	
Phase 3 (General release)	None		0
Capacity building			
Phase 1 (Laboratory)	Biosafety training for scientists	20 scientists from region @$1450 ea 2 presenters @ $3800 ea. Admin. (3 days)	29000 10600 4400

	Database information collection on biosafety of cowpea and the constructs	40h @$40	1600
Phase 2 (Field trials)	Biosafety for regulators	20 regulators- from region (3 days) @ $1850 ea. 2 presenters @ $4000 ea. Admin.	36000 8000 5000
Phase 3 (General release)	Assistance with application for regulatory approval	40h @$40 Travel	1600 4000
TOTAL			

Note: no adjustment has been made for inflation over the years. This may make a significant difference if the project extends over 14 years!

Who will do what and what funding agencies to approach:

Activity	Collaborators	Suggested funding agencies
Construct biosafety	Independent molecular biosafety expert in Australia	Add to construct development budget
Environmental safety	US universities + West African universities, or Add an EU environmental unit	UNEP EU – are calling for these proposals
Food safety	West African Food Science Institute (e.g. ITA) + French Institute + CSIR (food science)	EU
Capacity building	Innovation Biotechnology + regional biotech unit (e.g. African Agency for Biotechnology) – increase to 20 W. African scientists (20 cowpea, 20 other)	UNEP

Group 5

Trade, Marketing and Economics

Chairpersons: Ousmane Coulibaly and Jess Lowenberg-DeBoer

Participants: Mbene Faye, Amadou Dia

Introduction and Justification

Ultimately, whether seed is conventional or genetically modified (GM), it must be used within the context of a food system. This food system includes an agronomic cropping system that puts that seed into more or less fertile soil, manages weeds, pests and diseases and in general determines the environment in which that seed grows. The food system also includes a marketing system that takes the produce from the farm to the consumer. That marketing system includes transportation, handling, storage, processing and retailing.

At each step along the way, there are economic and social factors that determine when, where and how technology is used. If the technology does not increase farm profits, reduce risk or have other benefits, it is unlikely to be widely used. For genetic innovations which affect the production sector directly (e.g. pest resistance, herbicide tolerance), the marketing sector should at least not lose and potentially gain. Consumers who understand their benefit from GM crops are much more likely to accept them. Publicly supported research should have a special concern for the distributional consequences of innovations. How will the proposed innovation affect the poorest members of society? Do consequences differ by gender? Will the innovation help alleviate poverty?

As a consequence of the intimate link between elements of the food system, socio-economic research should proceed simultaneously with the biological work. A socio-economic analysis should be completed before substantial investment is made in any research path. In the private sector this analysis might be called a “market study” and would assure managers that the proposed innovation would create value. In terms of the research management literature, this analysis would be labeled an “ex-ante impact assessment”, but it would serve essentially the same purpose as the market study.

Social scientists should work closely with other researchers to ensure that the innovations fit the food system. Innovations should be affordable by the target farmers. It should be doable with their resources (e.g. human, monetary, land, labor). Input supply systems should be in place. The crop products should fit minimum consumer standards and ideally command a premium in the marketplace.

Current Status

Almost all adoption studies show that African farmers will adopt new crop technology if it has a substantial economic benefit. The key is to estimate the economic benefit deducting all costs, including transactions costs, opportunity cost of capital. Biotechnology innovations will be adopted if they can provide concrete benefits for farmers.

There have been few studies of potential for biotechnology in Africa. Faye (1999) examined the economic potential for cowpea varieties resistant to field insects in Senegal. She assumed that the yield loss on unsprayed cowpea is 40% and that the GM cowpea could achieve 90% of potential. She also assumed that the GM cowpea would be developed in the public sector and made available without a "tech" fee. She assumed a "plateau" adoption rate of 40%. She found that such research would have a rate of return of 48% annually and would generate a net present value of 330 million FCFA in Senegal alone. The benefit of insect resistant cowpea came from yield increases on current cowpea area and an increase in the area of cowpea per farm. Huesing (2001) reports that small holder farmers in South Africa benefit proportionately more from Bt cotton than larger scale commercial farmers.

Consumer preference studies on cowpea have only started in the last few years. All the Bean/Cowpea CRSP cowpea price and quality studies show that West African consumers pay a premium for larger grain size and that they are more sensitive to bruchid damage than previously hypothesized. Faye et al. (2000) showed that consumer preferences for cowpea color differed by region. Those in Sagatta paid a premium for white cowpea, while in Nioro and Dakar Castor consumers paid a premium for black speckled cowpea. In the Bambey area red cowpea are preferred; consumers say that even if you are too poor to afford a sauce, the red cowpea colors your rice a little. Langyintuo et al (2000) showed that Ghanaian consumers paid a premium for blackeye cowpeas, but blackeyes were discounted in Cameroon. There have been no published consumer preference studies for cowpea in southern Africa, but informal observations indicate that leaves used as a vegetable are more important in that market (Lowenberg-DeBoer, 1998). All the consumer preference studies to date depend on visible characteristics (e.g. color, grain size, number of bruchid holes, rough skin), but it is hypothesized there are chemical and other factors that also influence price. These other factors include sugar content, protein level, flatulence factors, and cooking time.

Impact of research and technology transfer for cowpea innovations are well documented. In Senegal, Operation Cowpea in 1985 and 1986 showed very high rates of return. Faye and Lowenberg-DeBoer, 1999, showed that the sequent varietal and storage research at ISRA (after operation cowpea) had a rate of return of about 16% annually. The drum storage technique developed by ISRA with CRSP partnership is used for about 80% of cowpea stored in Senegal. Diaz-Hermelo and Lowenberg-DeBoer, 2000 showed that storage research in Cameroon paid for the costs of research with adoption in Cameroon alone; net benefits are occurring with extension of that technology in eight other countries, including Nigeria, Tchad, Niger, Ghana, Benin, Mali, Senegal and Mozambique.

Regional cowpea trade in West Africa is documented by Jess Lowenberg-DeBoer and Coulibaly (2000). The general organizing principle of the trade is that carbohydrates move north and protein moves south. The Sahelian region has a comparative advantage in livestock, cowpeas and groundnuts. The more humid coastal regions can produce cassava, rice, plantain, maize, but because of livestock diseases and insect pressure they have high production costs for most protein sources. The largest cowpea producer and consumer in the world is Nigeria with about 2 million MT produced annually. The largest cowpea exporter in the world is Niger, with annual exports over 200,000 MT, mainly to Nigeria.

Input supply is a problem in much of Africa, especially for seed. Improved seed is more site specific than most other crop inputs. The genetics must fit the season length, pest pressure, disease complex and other local factors. High quality seed must be carefully handled to maintain germination. African farmers can use imported "generic" fertilizer and insectides, but the seed must be tailored for their conditions. Several studies exist of the seed sector in southern Africa. Both regional and multinational seed companies function in that market. The basis of their commercial success is the annual sales of hybrid maize, but they have branched out to other crops including cowpea. The West African seed sector is very weak. In spite of massive donor investments in the 1970s and 1980s, government seed agencies never became viable. Multinationals have tried to operate in the region and failed (e.g. Pioneer in Cameroon). While country level seed studies have been done in West Africa, there is no regional summary of the West African seed sector. Such a summary would be essential for any company or donor considering an investment in that area. In all parts of Africa, donors and NGOs seem to be focusing on community-based seed production. In spite of concerns about the quality of seed produced, this is a growing part of the seed supply in many areas.

Objectives:
Given the state of knowledge, the objectives of this research will be:

1) identify key opportunities and constraints in the West African seed subsector,
2) estimate the potential socio-economic impact of pest resistant GM varieties in Africa,
3) determine consumer demand for cowpea characteristics, especially non-visible characteristics such as taste, texture, anti-nutritional quality, protein content, oil content, etc.

Approach:

The socio-economic research would be led by Ousmane Coulibaly, IITA, and J. Lowenberg-DeBoer, Purdue University. It would draw on the expertise and experience of the Bean/Cowpea CRSP economics working group and the economists participating in Projet Niébé pour l'Afrique (PRONAF). These two groups include economists from: Senegal, Mali, Burkina Faso, Niger, Nigeria and Ghana.

The seed study would be done in three steps: 1) bibliographic research, pulling together country seed studies, 2) interviews with key informants in the region, and 3) a meeting of seed sector leaders to discuss the next steps. Interviews would focus on countries and aspects that are not covered in existing studies. The seed study would not be specific to cowpea. An economically viable seed organization cannot handle just cowpea; it must handle a range of crops. The bibliographic research and interviews would be summarized, identifying key opportunities and constraints. The seed sector meeting would take place in West Africa during the second year of the project. It would include crop seed companies doing business in West Africa (e.g. Pannar, Seedco, Nigerian Seed Company), as well as representatives from NARS involved in seed sales to farmers and NGOs (e.g. World Vision). The economics group will interact with the breeding, seed supply and commercialization working group in this effort.

The socio-economic study would be done in three steps: 1) representative farm analysis for selected locations; 2) summarization of economic benefits over time using the standard economic surplus analysis (e.g. Masters et al, Alston et al.), and 3) sensitivity analysis under various trade and policy scenarios. The representative farm models will follow the methodology used by Faye (1999). This study used a representative farm linear programming model to estimate the potential use of insect resistant cowpea in Senegal. The modeling approach is preferred in this case instead of an opinion survey because West African farmers have no experience with the technology in question. Their opinions on the subject would be pure speculation. It is impossible to do an analysis for each country. The plan is to analyze the situation in three or four representative locations in West Africa and one in Southern and Eastern Africa. Initial work would occur for locations with existing models that could be adapted. Faye's Senegal study would be updated and refined. The model outlined by Abdoulaye and Lowenberg-DeBoer (2000) would be utilized for Niger. The farm model developed by Langyintuo for the Guinea Savannah of Ghana would be adapted. One farm level model would be developed or adapted in southern and eastern Africa during the second year of the effort.

Relevant trade and policy scenarios for the sensitivity testing would be developed through discussions with economists at Purdue University, IITA and the participating NARS. The scenarios might include alternative price relationships and phytosanitary barriers the keep GM cowpea from certain markets. The economics group will link to the cowpea transformation and useful genes working group, and the policy framework, intellectual property and regulation in this effort.

The consumer preference analysis would use the hedonic pricing approach reported by Faye et. al. 2000, and Langyintuo et al., 2000 at the World Cowpea Conference. Cowpea samples would be purchased once per month in several markets and characteristics determined in the laboratory. Statistical techniques limit the number of continuous variables to three or four in most cases. The laboratory analyses to be carried out should be chosen in light of the capacity of food labs to carry out the analyses on a relatively large scale. For example, the current price and quality study in Senegal collects about 30 samples per month. Four tests on each of the samples would be 120 tests per month. The economics group will work with the food, environment and safety issues group in this area.

Timeframe & Responsibilities:

Year 1
West Africa Seed Sector Study - Should be started as soon as possible. Preliminary report in 6 months. Summary report in a year. Coulibaly and Lowenberg-DeBoer will share responsibilities.

Socio-economic potential - Should be started as soon as possible. Coulibaly and Lowenberg-DeBoer will supervise this work and identify trade and policy scenarios. Faye will update the Senegal model. Langyintuo will modify the Ghana model for the proposed GM cowpea. Aduayom will modify the Niger model. A Purdue graduate student supervised by Lowenberg-DeBoer will summarize benefits over time in an economic surplus framework. Policy analysis matrix (PAM) results on the profitability of cowpea will be complied at IITA. Baseline impact results for West Africa will be completed by the end of the year.

Consumer preferences - to provide the maximum information for breeders, data collection should start as soon as possible in the pilot location. Coulibaly, Faye and Lowenberg-DeBoer will meet with food scientists at that location to determine laboratory tests to be run and the logistics of testing. It is suggested that the pilot study be carried out in Senegal in collaboration with the Institute of Food Technology (ITA), Dakar. Faye would be responsible for in-country supervision of the tests.

Year 2
Seed Sector - Meeting with seed sector leaders.

Socio-economic potential - Policy and trade sensitivity testing. Final report on West Africa by the end of the year. Begin work on farm level analysis in one southern or eastern Africa country by the end of the year.

Consumer preferences - Data collection continues. Preliminary report on first year data by end of the year. Begin data collection in southern Ghana cities.

Year 3
Consumer preferences - Data collection continues. Preliminary analysis of Ghanaian data. Wrap up data collection for Senegal and do final analysis.

Socio-Economic potential - Update West Africa analysis as more data becomes available on the eventual technology and the policy environment. Complete impact assessment for Southern and Eastern Africa.

Year 4
Consumer preferences - Wrap up data collection in Ghana. Do final analysis

Socio-Economic potential - update analysis as more data becomes available on the eventual technology and the policy environment.

Subsequent years

Socio-Economic potential - update analysis as more data becomes available on the eventual technology and the policy environment. Maintain communication between social and biological scientists. Budget funds as necessary for specific activities.

Cost:
The estimated direct cost of proposed activities is given in Table 1. The estimate assumed that the seed study is handled by an IITA research associate, the West Africa impact assessment is done by a Purdue graduate student and the Southern and Eastern Africa impact study is done by a student at a South African University. The student doing the southern and eastern Africa study would probably be from the country where the farm level study is focused. In Senegal the laboratory analysis of the market samples would be done by ITA. In Ghana the analysis might be done by either the Food and Nutrition department at the University of Ghana Legon or by the Food Research Institute (FRI).

Table 1. Direct Costs of Proposed Economics Activities

Item	Year 1	Year 2	Year 3	Year 4
Seed Sector				
Research Associate	10,000			
Travel	3,000	40,000		
Communications, S&E	1,000	1,000		
Total	14,000	41,000		
Impact				
Students	32,000	32,000	32,000	
Travel	4,000	4,000	4,000	
Communications, S&E	1,000	1,000	1,000	
Total	37,000	37,000	37,000	
Consumer Preference				
Personnel	2,500	5,000	5,000	2,500
Travel	2,000	4,000	4,000	2,000
Communications, S&E	1,000	2,000	2,000	1,000
Laboratory Analyses	36,000	72,000	72,000	36,000
Total	41,500	83,000	83,000	41,500
Overall Total	92,500	161,000	120,000	41,500

Group 6

Breeding, Seed Supply and Commercialization

Chairpersons: B.B. Singh and Barry McCarter

Participants : Mamadou Balde, Ndiaga Cisse, Joe DeVries, Issa Drabo, Jeff Ehlers, Mohammad Ishiyaku, Harold McCauley, Mamadou Toure

Introduction:

Cowpea is the most important food legume in Africa, providing a cheap source of protein, as well as income for millions of resource poor families. Of the 12.5 million Ha total area under cowpea cultivation in the world, about 65% is in West and Central Africa In spite of its importance, few resources have been allocated to address the many constraints to improved productivity through crop improvement. Although there are many constraints, the most important ones that can be addressed through conventional plant breeding or biotechnology are:

Biotic Constraints

- Insect Pests
  - Aphids
  - Thrips
  - Maruca pod borer
  - Pod sucking bugs
  - Bruchids
- Diseases
  - Fungal- (Septoria, Scab, Ascochyta, Macrophomena)
  - Viral- (Aphid borne mosaic virus, Cowpea yellow mosaic virus)
  - Bacterial- (Bacterial blight)
- Parasitic Flowering Plants
  - Striga
  - Alectra
- Nematodes

Abiotic Constraints

- Drought
- Heat
- Low Phosphorus Use Efficiency
- Cold Tolerance

Agronomic Constraints

- Maturity
- Plant type
- Photosensitivity
- Yield Potential
- Biomass

Grain Quality

- Color
- Size
- Seedcoat texture

Nutritional Quality

- Protein content

Seed Production and dissemination

Strategy

Conventional breeding methods will be used to address those constraints where high level of genetic variability has been identified and effective screening methods are available. However, for traits such as resistance to Maruca pod borer, pod sucking and bruchids, where none or only moderate levels of resistance have been identified, we recommend that aggressive efforts be made to transfer resistance genes from other species with genetic engineering. Also, for traits such as bacterial blight, Striga, photosensitivity, drought, etc, that are difficult to select for in the field, we recommend markers be identified and marker-assisted selection techniques implemented.

The cowpea seed supply system in West Africa has been ineffective in supplying seed of improved varieties. We recommend a study be undertaken to identify ways to make the system work. This study should also address the cost and logistical implications of selling genetically modified (GM) seed of cowpea to small-holder farmers. In the meantime, when new varieties are developed, the National Breeding Programs should produce at least one ton of breeders' seed for production of Foundation Seed by appropriate agencies.

The objectives of this proposal are to develop improved cowpea varieties adapted to the various agro-ecologies of Africa. In the immediate future, genetic engineering is likely to offer great potential benefits to cowpea producers in Africa, especially in helping to greatly reduce losses in yield and reductions in grain quality due to insect pests. For this to happen, strong national breeding programs are needed to develop locally adapted varieties with the improved traits. Also, recent advances in molecular genetics, such as marker-assisted selection, that have the potential to speed up progress of breeding programs, are unlikely to be utilized in cowpea improvement unless the national programs in the region are strengthened.

We have identified the top 8-cowpea producing countries in Africa. In each of these countries there is, or soon will be, substantial cowpea breeding expertise. However, the effectiveness of these programs will be limited by poor infrastructure and low operating budgets for breeding without donor support. The eight countries, listed in order of cowpea production, are:

Nigeria	Senegal
Niger	Ghana
Burkina Faso	Cameroon
Mali	Benin

The most effective environment for screening segregating populations and other germplasm, and each major constraint that can be addressed with conventional plant breeding are:

Nigeria:
Zaria - Septoria, Scab, Bacterial Blight, Maruca, Alectra, Cold Tolerance
Kano - Striga (race 3), heat, Nematodes, Photosensitivity
Jos - Ascochyta blight

Mali:
Kapolo - Striga (race 2), Low fertility
Sikasso - Cowpea Yellow Mosaic Virus

Cameroon:
Maroua - Striga (race 5), Cowpea Aphid Borne Virus

Niger:
Niamey - Macrophomena

Burkina Faso:
Kamboinse - Aphid, Bruchids
Kobe - Striga (race 1)

Senegal:
Louga - Drought, Amsacta
Nioro - Thrips

Benin:
Zakpota - Striga (race 4)

US
Riverside - Nematode, Pod Sucking Insects

Farmer input into the breeding objectives and during evaluations of breeding lines will be an important component of this effort.

Needs for strengthening National Cowpea Breeding Programs

There is a need for facilities to make crosses, advance populations, screen germplasm, segregate populations, and conduct multilocation yield trials. This requires the following facilities for each participating country:

Screenhouse
Vehicle (double-cab pickup)
Irrigation facility for off-season nurseries
Technical Support Staff
Balances and Field Scales
Computer and Communication Facilities (Mail/E-mail/Internet capability)
Supplies
Labor
Fuel and Vehicle Maintenance
Travel (professional meetings, regional interaction)

Budget

Nonrecurring(Capital)

Item	Amount
Screenhouse	$15,000
Computers (PC, & laptop)	$ 5,000
Vehicle (double-cab PU)	$25,000
Balances, Scales	$ 3,000
Irrigation equip. (incl. Fencing for 1 Ha)	$20,000
Total	**$68,000**

Recurring

MS level technician	$ 6,000
Field Expenses (10 Ha Nurseries, Trials)	$15,000
Vehicle Maintenance (incl. Fuel)	$ 5,000
Communication Expenses (Tel. Fax, Mail)	$ 5,000
Regional and International Travel)	$ 5,000
Training	$ 5,000
Total	**$41,000**

Group 7

Stakeholder Input and Public Information

Chairpersons: Johnson Olufowote and Russell Freed

Participants: Mansour Fall, A.B. Salifu

Problem: Very little awareness of GMO issues.
Stakeholders are government, farmers, consumers, private sector, press, and students

Constraint definition:

1. Public needs to be informed of potential benefits and risks of genetic improvement, especially where biotechnology is proposed to be used.
2. Important to have stakeholder meetings to identify research and policy issues. Do this through community and farmer-based organizations.

Importance:

1. Without information, informed decisions/choices cannot be made on food safety, environmental, biodiversity, ethical, intellectual property, and policy framework.

Potential impacts;

1. Government/people will be aware of the safety of GMO crops
2. Consumers/markets will accept GMO cowpea and other crops

Approaches:

1. Develop information about the GMO process and what benefits/risks will accrue.
2. Simple illustrated pamphlet on GMOs and its potential application to cowpea (this will apply to other crops.) Also develop a website for cowpeas
3. SABRAD has material that can be modified for this effort. Other groups also may have material that can be used/modified. Need to identify a person who is responsible for this effort.

Methods of procedure;

1. Pamphlets to be made available to stakeholders;
2. Work with NGOs, public/private sector;
3. Work with other groups in this effort;
4. Develop press releases;
5. Sensitize research scientists, policy makers, consumers, students, press, and farmers.

Budget:

First Year:

Stakeholders Workshops/ 3 x 20,000	= 60,000
Materials Development	= 10,000
Press meetings/releases	= 20,000
Travel, etc	= 10,000
Total	**= 100,000**

Year 2 – 5:

Projected to cost **USD 25,000** per year

Grand Total: ***USD 200,000***

Potential Funders:

1. Bilateral/multi-lateral donors
2. Private sector
3. Foundations
4. National and International (FAO, ABSP, ISNAR) organizations.

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On the Genetic Improvement of Cowpea

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