Research Proposal: Overcoming Abiotic and Biotic Constraints to Yield, and Production of High Quality Peanuts in West Africa and Texas.

Principal Investigator

Mark Burow
Texas A&M University
AgriLife Research and Extension Center at Lubbock
1102 East FM 1294
Lubbock, TX USA 79403
Phone: +1 (806) 746-6101
Fax: +1 (806) 746-6528
Email: mburow@tamu.edu

Co-Project Investigator(s)

Nicholas Denwar
Legumes Improvement Programme
Savanna Agricultural Research Institute
P. O. Box 52
Tamale
Ghana
Phone: +233 20 9369976
Email: nicholasdenwar@yahoo.com

Ousmane Ndoye
ISRA-CNRA BP
Bambey, TX 764010004
Phone: () 973-6348
Email: ousndoye@refer.sn

Philippe Sankara
University of Ouagadougou
Departement de Phytopathologie
BP 7021
Ouagadougou 03
Burkina Fasso
Phone: 226-50-36-59-12
Email: philippe.sankara@ird.fr

Charles E. Simpson
Texas A & M University Agrilife Research
1229 North U.S. Hwy 281

Stephenville, TX USA 76401
Phone: +1 (254) 968-4144
Fax: +1 (254) 965-3759
Email: c-simpson@tamu.edu

Geographical Locations
Burkina Faso, Ghana, Mali

Submitted
09/30/2007

Focus
Domain - Production Values Region - West Africa

Background

1. Declining aquifer levels in Texas are a serious threat to long-term peanut production. In West Africa, enlargement of the Sahel threatens crop production, endangering the livelihood of people in affected regions and contributing to poor health through aflatoxin contamination. Drought- tolerant cultivars are needed to allow production in marginal areas of Africa, and to conserve underground water and improve sustainability of peanut production in Texas.
2. Peanut quality is important in all regions. In West Texas, early maturity is needed to eliminate off-flavors that can occur in immature seeds. Peanuts with enhanced oleic: linoleic ratios have improved shelf life and can reduce the incidence of coronary artery disease. In Senegal, early maturity is needed to escape terminal drought, and fresh seed dormancy among erect (Spanish) peanuts is needed to prevent seed germination in the field at maturity when late season rains occur. In Ghana, improved flavor and seed size for the edible market are needed, and erect types are preferred for the ease of hand harvesting and pulling pods from the plants.
3. One of the primary uses of peanut is for cooking oil. Most varieties have from 46% to 51% oil, and raising this to 50 to 55% would increase the oil yield comparably without an increase in acreage. Combined with the high oleic trait, this can raise the value of the crop to farmers and to consumers.
4. Early and late leaf spot cause major yield losses. Fungicides are not generally available in Africa, and although available in Texas, they are expensive. Resistant varieties are preferable for increased production and lower production costs. Wild species have strong resistance but linkage drag to low yield and late maturity. Some accessions in the cultivated species possess a degree of resistance, and ICRISAT has released breeding lines with favorable traits.
5. One of the most limiting factors to seed production in many countries has been the lack of seed programs to make quality seed of new

varieties available to farmers. Training in quality seed production is needed, and as is expanded collaboration with NGOs working to improve seed distribution to farmers.

6. Genomics is an important tool for varietal development, and the needed genomics tools are being developed in peanut now. Microsatellite markers will greatly accelerate progress compared to RFLP markers, allow marker-assisted selection in cultivated peanut, and is more appropriate for developing countries. Training in marker methods can be accomplished as part of graduate study in breeding.
7. Training in seed production, and breeding for drought tolerance, oil, and leaf spot resistance, and biotechnology are key aspects. Involvement of women in this area has potential for addressing gender inequality and has potential to influence the next generation of students.

Technical Review

1. In Texas, we have identified improved water use efficiency and heat tolerance in a subset of the US peanut minicore collection. We have also identified differentially-expressed genes and proteins by microarrays and proteomics (Kottapalli et al., submitted). Candidate genes for drought tolerance have been cloned by us and others (Guo et al, 2006, Clavel et al., 2006). We have characterized the minicore by SSR markers for association mapping (Kottapalli et al., 2007). We expect to use these advances to develop drought-tolerant cultivars.
2. In Texas, high-yielding, high-oleic runners two weeks earlier than standard varieties are candidates for release, as is a high-oleic Spanish line with improved maturity. Attempts to introduce genes from A. praecox (45 days to maturity) into cultivated peanut have had partial success, with backcrosses being completely sterile. Testing the nature of the missing chromosomes by RFLP analysis may give ideas for new strategies.
3. Peanut varieties in the US have from 46 to 51 percent oil (Burrow, unpublished). Some A. hypogea germplasm has up to 57% oil (Cherry, 1971), and section Erectoides up to 64% oil. Recent plant exploration has discovered a possible bridge species, and preliminary crossing data indicate that transfer of oil genes from Erectoides to cultivated peanut by breeding is likely (Simpson, unpublished).
4. Some wild species are highly resistant to leaf spot, and we have strong resistance (but low yield and late maturity) in BC2 and BC3 introgression lines. Linkage between low yield and resistance for the nematode resistant cultivar Nema TAM (Simpson et al., 2003) was broken after 7 cycles of backcrossing; the last two assisted by markers. We have continued backcrossing to Texas and Senegal varieties, and DNA is extracted for marker analysis. Sources of resistance in the cultivated species include erect Overo (S. American) landraces and ICRISAT germplasm (Upadhyaya et al., 2002 and others). Initial crosses have been made with the Overo lines.
5. In Texas seed multiplication and release is done by growers under the

auspices of the Texas Foundation Seed Service, and sale of seed to farmers by private companies. Seed multiplication in Senegal and Burkina Faso have not been as effective, and assistance from farmers' organizations and NGOs is being sought.

6. Molecular markers are a useful aid to breeding. We are currently mapping SSR markers and expect to have the first SSR-based map involving cultivated peanut by the end of the year. Microsatellite markers have identified polymorphism rates of up to 25% among cultivated accessions. We can map some cultivated x cultivated crosses, and we have found markers for pod shape and seed size in cultivated crosses.
7. Training (see below).

Problem Statement

Peanut production in West Texas and Africa alike face similar challenges of water stress, disease, and quality. Declining aquifer water availability in Texas threatens the long-term future of peanut production, and the encroachment of the Sahel southwards threatens crop production in northern regions of Senegal and Burkina Faso. Leaf spot causes serious yield losses in Africa, and requires expensive chemical applications in Texas. Consumer demands for high quality peanuts means that in addition to yield, breeding for quality is necessary for consumer acceptance. This requires earlier maturity and high-oleic peanut in West Texas; market conditions in Ghana and Senegal require production of higher quality peanuts. We propose common breeding projects in these areas, integrating use of molecular markers to enhance the effectiveness of the breeding programs.

Multiplication of seed of improved varieties and delivery of seed to farmers is necessary for breeding efforts to have impact. These have been problematical in Senegal and Burkina Faso, and we will collaborate with NGOs for delivery of seed of new varieties to farmers. Short and long-term training will improve capacity in seed release, breeding, and application of marker technology to breeding, and provision of required infrastructure will improve autonomy and sustainability of programs.

Vision and Approach

Goals

A successful outcome will result in being able to develop peanut varieties that are higher in quality and oil content, are tolerant to drought and foliar disease and thus having a high level of sustainable yield, and are developed in a short period of time by use of breeding techniques incorporating molecular markers. These new varieties would be successfully multiplied so that quantities of seed would reach the West African farmers within two years of release and there would be a sufficient quantity of seed available each year for planting. Capacity development will result in greater ability and independence in developing and applying technologies, and in greater opportunities for women in research.

Objectives

1. Identify additional accessions with tolerance to drought and heat stress and early maturity, and use them to develop drought-tolerant varieties.
2. Develop and release early-maturing, high-quality peanuts that have improved flavor (Texas) and larger seeds that have higher value for the edible market (Ghana).
3. Develop peanuts with high oil content.
4. Combine high yield, early maturity, and leaf spot resistance, and test fungicide applications for their effectiveness and costs.
5. Improvement of the seed release mechanism, multiplication of seed for varietal release, and distribution to farmers.
6. Develop and apply molecular markers for trait breeding
7. Training.
8. Improve infrastructure in Burkina Faso.

Research Approach

1. Abiotic stress.
    a. Screening for tolerance will involve field testing under irrigated and drought conditions. In Texas SPAD readings, flowering, paraheliotropism, yield, shelling, and harvest index will be taken; greenhouse readings will include PSII fluorescence, acquired thermo tolerance, and gravimetric water use efficiency.
    b. Crosses will be made to combine abiotic stress tolerance with adapted Spanish (Africa) and runner (Texas) peanuts.
2. Quality.
    a. Screening for advanced breeding lines will involve testing for yield, shelling, maturity, oil composition (Texas).
    b. Crosses with A. praecox will involve diploid section Arachis species, then use of tetraploid or hexaploid routes to cross with cultivated peanut.
    c. In Ghana, edible peanut breeding will involve crossing large-seeded high-oleic cultivars by local cultivars. Oil composition will be determined at TAMU by NIR or gas chromatography.
3. High oil peanuts.
    a. Crosses will be made between cultivated high oil parents and local cultivars. Oil analysis will be done by NMR at TAMU.
    b. A pathway to introgress high-oil genes from section Erectoides will be developed by crossing potential bridge species both with Erectoides and Arachis diploids. Hybrids will be intercrossed, then crossed by cultivated peanut after chromosome doubling.
4. Leaf spot resistance.
    a. Backcrossing of introgression lines will continue, using local cultivars as recurrent parents. Selection will be made in Burkina Faso, Ghana, and Texas for pod yield, resistance, maturity, and (Ghana) stover yield. Markers for resistance will be identified by

RFLP or SSR analysis.
   b. SSR-based marker-assisted selection will be done to aid backcrossing, and training will involve analysis of African materials. Near-isogenic introgression lines will be made with assistance of markers.
   c. Overo or ICRISAT resistant lines will be crossed by local cultivars and evaluated as above.
5. Seed Multiplication and release.
   a. Training on seed multiplication and distribution will be conducted at Texas A&M and the Texas Foundation Seed Service.
   b. In Senegal, initial multiplication will be overseen by ISRA, with subsequent multiplications by farmer's organizations ASPRODEB and CCPA. In Burkina Faso, this will be done in collaboration with the NGO ATTRA.
6. Genomics.
   a. Identification of markers for leaf spot resistance will be completed using RFLPs or SSRs if the SSR map is ready. QTLs will be analyzed using QTL Cartographer.
   b. Chromatin from wild species will be identified using SSR markers for backcrossing and for development of near isogenic lines.
   c. Markers for drought tolerance will be primarily SSRs plus some candidate genes, mapped using 1 population each for Africa and Texas.
   d. Association mapping of SSR markers for abiotic stress tolerance will be done using mixed model methods.
7. Training. See below.

Training & Capacity Development Approach

a) Long term training for graduate students will take place at Texas Tech. The first is completion of the doctoral studies of Nicholas Denwar in breeding and markers for leaf spot resistance in 2008. A new training program will be conducted as a sandwich with a host country, and will involve breeding for drought tolerance in Africa, and screening for markers and physiological traits at TAES and the USDA.
b) Training for seed quality and release mechanisms will take place at the Texas Agric. Expt. Station and Texas Foundation Seed Service. This will involve one person each from Senegal and Burkina Faso (Traore Idrissa) learning the seed multiplication, distribution, storage, processing, and marketing system in Texas, as well as participation in pertinent tours by the American Peanut Council, Georgia Peanut Board, and Peanut CRSP. Duration will be approx. 6 months to allow observation of the workings of the system at different times in the year. Traore Idrissa is expected to become a technician in the Sankara laboratory.

Intended Benefits & Impact Responsiveness

Development Benefits

Development of drought-tolerant peanut will assist farmers living under marginal conditions, especially in northern parts of Senegal and Burkina Faso. Early maturity will likewise help in escaping the effects of drought. Drought tolerance has the potential for reduction in aflatoxin contamination, improving health of consumers by reduction in liver cancer and immune system suppression. Development of erect type peanuts in Africa saves labor for women, as they perform much of the post-harvest work. Higher quality peanuts for the edible market will improve farm income by higher prices for the crop, and high oleic peanuts can improve coronary health. Leaf spot resistance will reduce defoliation, leading to improved pod yields and farm income, also aiding farmers by providing additional food for animals, as leaves and stems are used as fodder. The seed project could be highly significant for the peanut farmers in West Africa, by improving the ability to transfer releases into actual varieties grown. Use of SSR markers will accelerate breeding progress, and is more appropriate for developing countries than RFLP markers. Training in seed production, breeding, and biotechnology will enhance local capacity. Involvement of women in this area is significant for addressing gender inequality as it has the potential to influence the next generation of students.

US Benefits

Development of drought-tolerant peanuts is needed for sustained production of peanuts in West Texas, and will be useful for South Texas as increasing urban water demands compete for groundwater. Release of early-maturing, high-oleic peanuts will improve the flavor and quality of peanuts from Texas and have important health benefits. Development of high-oil peanuts for the U.S. that could be used for bio-fuel, and not be grown in competition with edible peanut, would be part of a larger plan to reduce the dependence of the U.S. on foreign sources of energy. This can be done by growth under reduced inputs, or by seed color or shape not acceptable for the edible market. Incorporation of leaf spot resistance will allow reduction of costs of production, increasing U.S. competitiveness. Release of near-isogenic lines of peanut will benefit the entire peanut industry by making the resistance alleles from wild species more accessible to breeders. Identification of molecular markers will accelerate breeding efforts, especially when developing cultivars with complex traits such as drought tolerance and leaf spot resistance.

Potential Impacts

Impacts fall into three major categories. The first is release of improved cultivars, allowing greater efficiencies and profitability for farmers. Issues addressed are biotic stresses, water, labor, and minimizing purchased inputs. These will be achieved by utilization of the genetic diversity in peanut. Success in breeding will be measured as cultivars released, and acreage on which they are grown. This will require effective seed multiplication and distribution.

Secondly, consumers will benefit through development of improved peanut for the edible market, with high-oleic peanuts benefiting health (reduction in heart disease). This has been demonstrated previously, and will depend on growth of new cultivars.

Finally, improved capacity will strengthen breeding programs to meet the ever-changing challenges involved cultivar improvement. This will be measured as people trained.

The objectives here meet the Peanut CRSP goals for achievement of sustainable economic, institutional, and social improvement. In addition, they satisfy Millennium Development Goals (reduced poverty and hunger), Initiative to End Hunger in Africa (focus on Ghana, harnessing power biotechnology, and use of community and producer-based organizations), gender equality (training of women), enhancement of biodiversity, mutual benefits (Africa and Texas), improvement of health and nutrition, maximizing water productivity, and advancing IPM (improving genetic resistance).

Equipment

1. Equipment requested for Burkina Faso includes a small greenhouse for crossing ($24,000), and for training of students. A truck is also requested to replace the current one; the price in Burkina Faso is c. $45,000 but cost can be halved if purchased through USAID in Ghana.
2. Equipment for Ghana also includes a new truck for the program. Nicholas Denwar will assume the responsibility as peanut breeder, a new position, and will need this for carrying out his duties.
3. Senegal also requests a new truck, as the vehicle used previously belonged to a scientist who is no longer associated with the project. A DNA sequencer for fragment analysis is needed at CERAAS (Senegal), but because of the cost (>$70,000) and type of equipment, this request is more appropriate for a genomics proposal.

Project Timeline

1. Drought tolerance. Years 1-2: Screening of minicore collection (Texas, Senegal, and Burkina Faso). Years 3-5: population development and screening, mapping of drought tolerance.
2. Quality. Years 1-3: Release of early-maturing runner and Spanish cultivars (Texas), and of early-maturing and seed-dormant cultivars (Senegal). Years 2-5: development of additional early-maturing lines (Texas), and large-seeded Spanish peanut for the edible market (Senegal, Ghana).
3. High oil peanut. Years 1-2: initial crosses for high-oil peanuts, attempts to make interspecific hybrids with section Erectoides. Years 3-5, selection for high oil, crosses of Erectoides hybrids with cultivated

peanut, followed by backcrossing.

4. Leaf spot resistance. Year 1: finish marker analysis. Years 1-2: Make backcrosses to local cultivars. Evaluate Overo and ICRISAT accessions, make crosses. Years 3-5: break unwanted genetic linkages in interspecific lines, generate near-isogenic lines.
5. Seed multiplication and distribution. Years 2-3: training (Texas), release of cultivars. Years 3-5: varietal multiplication and purchase by farmers.
6. Markers. Year 1: markers for leaf spot resistance, Years 3-5: marker-assisted introgression, Year 2-3, training, Year 4-5: markers for drought tolerance.
7. Training. Year 1; finish Nicholas Denwar PhD, Year 2-3: training for seed quality, Years 2-3: training for markers, Years 2-5: training for drought tolerance.

USAID Mandate Responsiveness

MDGs

Poverty/Hunger: Improved Health: Raised Rural Incomes: Sustainable Development

Foreign Assistance Framework

Governance: Human Capacity: Economic Structure: Persistent Dire Poverty: Global Issues (HIV and Infectious Diseases, climate change, biodiversity)

IEHA

Science and Tech Applications: Increased demand for peanuts: Market Access: Increased Trade

USAID Focal Areas

Greater incomes: Greater value and market demand: Public Health: Food Security: Sustainable Value Chain: Improved Human Capacity