Research Proposal: Strategies for Controlling Groundnut Rosette Disease in Sub-Saharan Africa: Breeding for Disease Resistance, Seed Dissemination, Disease Management Education, and Generation of Transgenic Groundnut with Resistance to Groundnut Rosette Disease.

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Title

Strategies for Controlling Groundnut Rosette Disease in Sub-Saharan Africa: Breeding for Disease Resistance, Seed Dissemination, Disease Management Education, and Generation of Transgenic Groundnut with Resistance to Groundnut Rosette Disease.

Focus
Domain - Production Values Region - E and C Africa

Background
A major constraint to growing groundnut in groundnut growing areas of SSA is GRD. This is especially true in Uganda, a developing country, where in most years GRD is the major limiting factor in groundnut production. Therefore, a primary factor in increasing groundnut production in Uganda and the East African region is developing a successful, sustainable management program

against GRD composed of GRD-resistant groundnut varieties and appropriate cultural practices. Presently the primary factor in managing GRD is GRD-resistant germplasm. Through funding from Peanut-CRSP, this approach has been especially productive during the last 5 years with the release of a number of groundnut varieties with resistance to GRD as well as drought tolerance (early-maturing). The inclusion of the early-maturing trait is important for avoiding late season drought stress and, subsequently, results in less aflatoxin contamination.

Non-technical Constraints: A number of non-technical constraints can be overcome using GRD- resistant groundnut varieties. While cultural practices are generally useful in lowering GRD incidence, they are generally not adopted by growers for numerous reasons. Early planting and maintaining a uniformly dense stand of groundnut greatly reduces the incidence of groundnut rosette disease. However, these practices are seldom adopted by the traditionally conservative smallholder farmers in SSA because they prefer planting their main staple food and cash crops first. Groundnut, providing sufficient seed is available, is many times left until later in the season or until the second rains. Groundnuts are grown in most of SSA as a subsistence crop under rain- fed conditions, either once or twice a year, depending on rainfall patterns. In many countries, farmers do not remove volunteer groundnuts and ground-creepers that start growing with the first rains. This permits aphid vectors to colonize and infect such plants, which in turn serve as primary sources of inoculum for the subsequently sown crops. In addition, early sowing may not be effective in areas with overlapping groundnut crops where the vector and disease agents perpetuate throughout the year. Many times, early sown crops must be harvested during wet weather, causing problems of drying and predisposition to fungi, which may result in the accumulation of mycotoxins. Furthermore, weeding of groundnut fields is often delayed due to labor constraints and, in many cases, due to the preoccupation of farmers with other food and cash crops, resulting in poor plant growth and significant yield losses.

Control by chemical pesticides is possible, but not practical. Insecticides have been used to control aphid vector populations to minimize spread of GRD in the field, but the approach is not economically feasible for most smallholder farmers in SSA.

Environmental issues: While farmers in SSA typically cannot afford insecticides, in areas where GRD-resistant varieties are not available insecticides have been used in an attempt to control the aphid vector. However, the improper use of these insecticides might alter the delicate balance between aphid vectors and their natural enemies, and possibly result in the development of insecticide-resistant biotypes. Therefore, a major benefit of developing and using GRD-resistant germplasm is the decrease in use of insecticides. Also, safety guidelines for using the insecticides are typically not followed, which results in increased risks to human health. On a positive note, as a legume, groundnut improves soil fertility by fixing nitrogen.

Gender: In many sub-Saharan Africa (SSA) countries, women predominantly grow and manage groundnut. Therefore, increased groundnut production resulting from available and effective GRD-resistant germplasm will have a direct bearing on the overall economic, financial, and nutritional well-being of women and children.

Health: For people in many developing countries, groundnuts are the principal source of digestible protein (25-34%), cooking oil (44-56%), and vitamins like thiamine, riboflavin and niacin. Increase groundnut production with GRD-resistance varieties having drought tolerance will result in a more stable, high quality food source, which will have a significant effect on health and alleviating poverty.

Technical Review

GRD is caused by a complex of three agents: groundnut rosette assistor virus (GRAV), groundnut rosette virus (GRV) and the satellite RNA (sat-RNA) of GRV. An aphid, Aphis craccivora Koch., transmits the disease. The intimate interaction between GRAV, GRV and sat- RNA is crucial to the development of the disease. GRV acts as a helper virus for replication of sat-RNA. The sat-RNA is primarily responsible for inducing the symptoms, while GRAV and GRV appear to contribute very little to disease symptoms. While a single aphid vector acquires GRAV, GRV, and sat-RNA, it does not always transmit the three disease agents together to a host plant. However, for the disease to perpetuate in nature, all three agents must be transmitted by the aphid vector to a plant. While the disease is only found in SSA, the vector is found worldwide.

Sources of resistance to groundnut rosette disease were first identified in groundnut land races of the late-maturing Virginia type in West Africa, but the major disadvantage of these cultivars was that they required a long growing season (150-180 days) to attain maturity, making them susceptible to drought during the end of the season. In addition to decreased yields, drought stress results in aflatoxin contamination and decreased groundnut quality. However, breeding programs were not successful in separating GRD resistance from the late-maturing trait. The challenge was to combine GRD resistance with early-maturing (90 to 110 days), high-yielding types suitable for smallholder farmers in different eco-systems of SSA. The Southern African Development Community/International Crops Research Institute for the Semi-Arid Tropics (SADC/ICRISAT) Groundnut Project launched a program in the early 1980s to develop such cultivars. This resulted in identifying several high-yielding, agronomically acceptable, short- and medium-duration groundnut genotypes with good levels of resistance to GRD. Several of these genotypes produce significantly higher yields compared to susceptible varieties, are medium- duration (Virginia bunch type) or short-duration Spanish type; ICG 12991) and have agronomic characteristics that, while not optimal, are acceptable to farmers and consumers. ICG 12991, which is resistant to the aphid vector, has been released in Malawi as 'Baka' and in

Uganda as 'Serenut 4T'. A previous Peanut-CRSP project (UGA28), which the collaborators of this PTP were actively involved in, assisted in screening, evaluating, and releasing the GRD resistant lines within Malawi and Uganda. About 100 long-duration Virginia types and 15 early-maturing Spanish types having a high level of resistance to GRD have been identified. These additional sources should be invaluable in breeding programs to broaden the genetic base of resistance and ensure stability of resistance. Therefore, to maximize their effectiveness, additional GRD- resistant material needs to be critically evaluated for performance against GRD in different environments. In addition, while ICG 12991 ('Baka'/'Serenut 4T') has been very successful in Malawi and Uganda (~25-35% of groundnut grown in Uganda) it is not preferred by farmers or consumers because if its small pod and seed size, tan seed coat, and some GRD incidence when planted late. Therefore, the need for GRD resistance in cultivars preferred by farmers and consumers (such as, Valencia and favored local varieties) are becoming increasingly important, both for enhancing production and post-production acceptance of groundnut.

Problem Statement

Problem: Groundnut rosette disease (GRD) is the most destructive viral disease of groundnut in sub-Saharan Africa (SSA). The disease, which is endemic to SSA, causes greater yield losses than any other viral disease affecting groundnut in the world. In addition to yield losses, GRD epidemics have a long-term debilitating impact on groundnut production since farmers typically decrease production following epidemics to avoid future risk.

Importance to development: In many developing countries of SSA, groundnuts are the principal source of protein, oil, and vitamins and also provide a cash income that contributes significantly to food security and alleviating poverty. As a legume, groundnuts improve soil fertility by fixing nitrogen, thereby increasing productivity of the semi-arid cropping systems. Therefore, yield losses resulting from GRD have a direct bearing on the nutritional and economic status of smallholder farmers in developing countries of SSA. Presently, limited field resistance is available against the disease in cultivars that have less than superior agronomic traits. While insecticide control of the aphid vector and cultural practices are known to reduce the disease incidence, they are seldom used by smallholder farmers for a number of reasons.

Importance to peanut science: Developing cultivars with resistance to GRD and drought tolerance will likely result in the identification of additional beneficial agronomic traits that could eventually be breed into other cultivars for groundnut growing regions of the world where the disease is not a problem.

Importance to the Partner HC: Uganda is a developing country in SSA that had 225,000 hectares under groundnut production in 2005. The majority of the Uganda population lives in rural areas. Approximately 85% of those are involved in agriculture and live in poverty. Groundnut has become part of the culture, is consumed locally, and is grown by smallholder farmers. In most years, GRD is the most important factor limiting groundnut production.

Importance to US interests: Increasing groundnut production in SSA will contribute to food security and poverty reduction. The outcome will be an increased awareness of groundnut, which could expand the international market for U.S. grown groundnuts and groundnut products. These benefits, in addition to increased education and training, will assist in promoting an infrastructure that will increase political stability and self-sufficiency. Lastly, the potential for GRD to emerge in the U.S. exists since the aphid vector is found worldwide, including the U.S. Therefore, having management programs in place for controlling GRD would be of great importance to U.S. groundnut production in the event the disease does emerge in the U.S.

Vision and Approach

Goals

The goals of the proposal are to develop and disseminate highly desirable groundnut cultivars with resistance to groundnut rosette disease (GRD) and drought tolerance to groundnut growing countries of SSA and to educate farmers on the use of the resistant cultivars with appropriate cultural practices to develop a management program against GRD. GRD-resistant cultivars from the ongoing breeding program will be evaluated for their performance against a range of variants of GRD-inducing agents in a variety of ecological zones of Uganda. In situations where the resistant cultivars are not acceptable or not preferred, the goal is to breed GRD resistance into agronomically acceptable varieties. GRD-resistant cultivars previously released will also be used for breeding resistance into preferred varieties. Preferred cultivars with GRD resistance, and drought tolerance, will be disseminated throughout the region. The long-term goal is that GRD-resistant cultivars will eventually be available to all ecological zones of SSA and along with appropriate cultural practices will result in the development of a sustainable disease management program against GRD throughout SSA. The drought tolerance trait will be retained so the crop will be less susceptible to drought during the end of the growing season. This later trait also results in reduced aflatoxin contamination and, thusly, provides for higher quality and healthier groundnuts.

Objectives

1. Evaluate GRD-resistant germplasm presently in Uganda that originated from the
2. ICRISAT-Malawi screening project for GRD resistance.
3. Breed GRD resistance from presently available resistant cultivars into cultivars preferred by farmers and consumers, such as Valencia varieties.
4. Seed increases for desirable cultivars having GRD resistance and drought tolerance for dissemination to Ghana and other groundnut growing countries in SSA.

5. Educate farmers on GRD-resistant cultivars and appropriate cultural practices for developing a sustainable disease management strategy, as well as for technology transfer issues.
6. Generation of transgenic peanut with genetic engineered resistance to groundnut rosette disease.

Research Approach

1. Breeding for resistance and other desirable characteristics, which will involve conducting experiments on selected promising lines at SAARI and several other locations in the groundnut growing areas of Uganda. This normally takes a minimum of three seasons (or 3 years) depending on the weather leading to reliable results. Some materials presently under evaluation are from the original ICRISAT-Malawi screening project. In addition, we have initiated crosses between the ICRISAT-Malawi lines with GRD resistance/drought tolerance and local varieties favored by farmers and consumers. The most promising ones will be advanced for performance evaluation studies at multi-locational testing sites. Numerous sites are hot spots for GRD in Uganda, so disease pressure is high. Following preliminary screening, advanced screening of selected lines focus more on a combination of desirable traits, such as yield potential, GRD resistance, drought tolerance, and other agronomic traits deemed important.
2. On-farm trials on farmers' fields will be conducted for the purpose of getting their preferences among the candidate varieties before proposing any of them for release. Lines selected for resistance, yield, drought tolerance and other agronomic traits such as pod shape, seed size, seed color, and uniformity will be evaluated in farmer's fields for stability and durability. The data from these trials has to be reflected in the release write-up.
3. After the release of any of the candidates, seed will be multiplied in reasonable amounts to feed into uptake pathways such as seed banks, farmer field schools, NGOs, Seed Companies, National Agricultural Advisory Services (NAADS) etc. At this point additional seed increases will be carried out, as necessary, for dissemination to other countries if requested regional press releases.
4. Information will be packaged and disseminated on the new varieties, as well as developing and implementing awareness programs for stakeholders on groundnut production and disease management. This will occur primarily at farmer field days, at commodity group meetings, and other agricultural related events.
5. We shall also establish demonstration plots at public places for outreach purposes to better educate additional farmers and consumers. In addition to released lines, information on technology transfer issues will be disseminated to increase consumer awareness on the benefits of biotechnology.

Training & Capacity Development Approach

The primary training goals are to disseminate information through farmer field days. This has been a very successful approach in the past and is expected to remain successful in the future. During training, new varieties and production technologies will be demonstrated. While cultural practices, such as early planting and maintaining a uniform density, can greatly reduce GRD incidence, these practices are seldom adopted for numerous reasons. One reason is that other crops take preference, but as groundnut production increases and more time is spend on the crop then cultural practices will become more practical and important in controlling GRD incidence when combined with GRD resistant cultivars. Therefore, cultural practices that decrease GRD incidence will be discussed and the importance stressed during farmer field days.

Farmer field days will also be used to increase awareness on technology transfer issues and their potential impact. This will be a proactive approach to educate growers and consumers on the benefits of using transgenic plants to provide stable resistance to GRD. This is also important since acceptance of transgenic plants for GRD will likely increase the rate of acceptance of transgenic groundnut expressing other value added qualities (i.e., glyphosate resistance), which will be addressed later in the PTP for Global 1-Biotech Tools.

The proposal will also support new and continued training of technical staff, which are involved in all aspects of screening and breeding for resistance. The number of technical staff that will be trained is expected to increase as groundnut production increases.

While student training is not presently planned, the need for more expertise in groundnut production and post-production activities in Uganda is likely. Therefore, as the grant progresses and the need arises, then student training will be further addressed.

Intended Benefits & Impact Responsiveness

Development Benefits

Increase production, in this case resulting from germplasm with resistance to GRD, will immediately assist poor smallholder farmers that grow the majority of groundnut by increasing their income and extend benefits that have already been realized. In many groundnut-growing countries of SSA women predominantly grow and manage the crop, from production through post-harvest and processing activities. Therefore, increased groundnut production has a direct bearing on the overall economic and financial well-being and nutritional status of women and children. Over time as increased production of GRD-resistant cultivars occur then multiplier effects take over. In rural communities increased groundnut production will generate jobs in production and post-harvest related industries. As production increases, then the poor in rural and urban areas will benefit as groundnut becomes more affordable and groundnut-related jobs increase. While these benefits have and will occur following newly developed and release of GRD-resistant lines, we expect these benefits to be even greater when increased production and consumption occurs following release of preferred consumer varieties with GRD resistance.

US Benefits

This PTP is directed at increasing production by developing a management program to control GRD in Eastern Africa. While this project provides some benefits to the U.S. it will be linked with a 'Biotech and Tools' PTP that will provide significantly more direct benefits to the U.S. Varieties resistant to GRD will improve groundnut yield and quality, which will contribute significantly to food security and in alleviating poverty. This will act to increase stability in the region by contributing to a healthier and wealthier population.

Increasing groundnut production will contribute to food security and poverty reduction. The outcome will be an increased awareness of groundnut, which could expand the international market for U.S. grown groundnuts and groundnut products. These benefits in addition to increased education and training will assist in promoting an infrastructure that will increase political stability and self-sufficiency. Lastly, the potential for GRD to emerge in the U.S. exists since the aphid vector is found worldwide, including the U.S. The movement of virus diseases across continents has been well-documented in several crops. Therefore, having management programs, especially resistant germplasm, in place for controlling GRD would be of great importance to U.S. groundnut production in the event the disease does emerge in the U.S.

Potential Impacts

With the continuing release of GRD resistant cultivars and the use of appropriate cultural practices we expect immediate and progressively improving groundnut production increases due to the development and dissemination of GRD resistant cultivars in Uganda and Eastern Africa, with the eventual dissemination of the resistant cultivars to Western Africa. The immediate impact will come from the use of GRD lines developed during the last Peanut-CRSP grant. These resistant lines are gaining acceptance in Uganda and will likely be well received in other SSA groundnut growing countries after germplasm increases are made and seed are disseminated. New GRD resistant lines presently in development with improved agronomic traits will continue to be released and new GRD resistant lines with farmer and consumer preferred agronomic traits will eventually be developed and released. The true impact will be represented by the percentage of groundnut production resulting from GRD resistant lines developed by this proposed research. As new lines that are presently being evaluated and lines that will be developed are released we expect a larger and larger percentage of the groundnut market to be represented by lines that have GRD resistance that came out of this proposed research. We expect this to occur quickly in Uganda and to begin spreading through groundnut growing countries of Eastern Africa as the grant progresses and the germplasm is disseminated.

Project Timeline

Objective 1

Years 1-5; Evaluate GRD-resistant germplasm presently in Uganda that originated from the ICRISAT-Malawi screening project for GRD resistance. Considerable resistant germplasm originating from ICRISAT-Malawi is in various stages of evaluation against a range of variants of GRD in different environments. Depending on resistance from a single source is risky. Therefore, to broaden the genetic base of resistance and enhance durability, other sources of resistance need to be evaluated. As the evaluations continue new lines will be releases if the level of resistance performs well and the line's agronomic traits are good. However, even lines that have good sources of resistance, but poor agronomic traits, will represent a future source of resistance, possibly unique, if needed.

Objective 2

Years 1-5; Breed groundnut resistance from present resistant cultivars into cultivars preferred by farmers and consumers, such as Valencia varieties. Since this objective will be initiated with this proposal, we see this objective running through the five years of the grant for development, evaluation, and release of favored local cultivars containing GRD resistance.

Objective 3

Years 1-3; Seed increases for desirable cultivars having groundnut rosette disease resistance and drought tolerance for dissemination to other groundnut growing countries in SSA. This objective is to disseminate seed from GRD-resistant groundnut cultivars presently released to groundnut growing countries primarily within Eastern SSA, although seed will be sent to Western and Southern SSA if requested. Three years should be sufficient to disseminate seed through Eastern SSA countries that want the GRD-resistant germplasm. This goal of this objective is to give sufficient seed to initiate a seed multiplication program by farmers, commodity groups, or commercial seed companies in other SSA countries.

Objective 4

Years 1-5; educate farmers on groundnut rosette disease resistant cultivars and appropriate cultural practices appropriate for developing a sustainable disease management strategy. This is an ongoing outreach objective that will continue through the life of the grant to educate farmers and consumers on GRD sustainable disease management strategies and technology transfer issues.

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