Peanut Research and Poverty Reduction:
Resistance Strategies to Control Peanut Viruses in Uganda

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Abstract

Economic impacts of research that developed Rosette Virus-resistance peanut in Uganda are estimated. Changes in economic surplus are calculated and combined with household data to assess changes in poverty rates and effects on livelihoods of the poor. The poverty rate among peanut producers may decline by as much as 3 percentage points as a result of the research.

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Introduction

Rural households in Sub-Saharan Africa depend heavily on agriculture, and peanuts are an important crop in many areas. Peanuts are the principal source of digestible protein, cooking oil and vitamins in many African countries, women frequently taking the lead in growing and managing the crop. Peanut productivity has a significant bearing on the economic and nutritional well being of a large segment of the population in such countries. Unfortunately, peanut production is affected by various viruses and diseases, the most common being Groundnut Rosette disease, a viral infection first reported in Tanganyika (now Tanzania) as early as 1907 (Gibbons). Groundnut Rosette disease has been responsible for devastating losses to peanut production in Africa. For example, the rosette epidemic in 1994-1995 in central Malawi and eastern Zambia destroyed the crop to such an extent that the total area of groundnut grown in Malawi fell from 92,000 ha in 1994-1995 to 65,000 ha in 1995-1996. Losses in Zambia were estimated at US$ 5 million during the 1995-1996 crop year. Overall losses due to rosette disease in Africa were estimated at about US$ 156 million per annum (ICRISAT).

Peanut varieties with resistance to Rosette virus have been developed in Uganda, a country where the majority of people live below a poverty line of US$ 1.00 per person per day and rural poverty is particularly pervasive (World Bank).[1] While peanuts are not as important to diets in Uganda as they are in West African countries, they are very

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[1] Research leading to the Rosette-resistant varieties was supported by the National Agricultural Research Systems, ICRISAT and the USAID-funded Peanut CRSP.

important in certain sub-regions, particularly in Eastern Province, where data for this study were collected.[2] Research leading to the virus-resistant variety in Uganda may have significant economic benefits, and more importantly, may have reduced poverty. Benefits may result from higher yields, lower production costs per quantity of output, less risk, lower food prices, and increased marketed surplus. The general consensus in the literature is that agricultural productivity growth has strong potential to be pro-poor. It can benefit poor farmers directly if they are able to adopt the new varieties. Depending on labor bias, technological change can help agricultural laborers by increasing demands for farm workers. It can benefit the rural and urban poor by boosting growth in the urban and rural non-farm economy. It can stimulate production of crops that are high in nutrients and empowers the poor by increasing their access to decision making processes, increasing their capacity for collective action, and reducing their vulnerability to shocks, through asset accumulation (Hazell and Haddad).

The distribution of benefits from Rosette-resistant peanut varieties may be biased toward the poor for several reasons. First, peanuts are mainly produced by small-scale farmers in Sub-Saharan Africa, the majority of which are poor. Productivity gains will raise incomes among adopters, possibly lifting poor families above the poverty line. Second, a resistant variety is a relatively simple technology, so that adoption may be independent of farmer's wealth. Peanut seeds are regularly purchased, since stored seeds lose their productive potential after 2-4 years; purchase prices of virus-resistant seeds may not represent a significant barrier to adoption. Third, production costs per unit of output for resistant varieties are lower than costs for traditional varieties, and productivity

[2] Consumption of peanuts is 6 kg/person/year in Uganda, compared to 14 for all Sub-Sahara Africa (FAOSTATS).

gains will be directly captured by producers. Finally, groundnuts represent a greater share of the consumption bundle of poorer households, allowing them to capture benefits of price reductions.

Scientists, research administrators and policy makers face increasing pressure to justify continued public investment in agricultural research. As demands for scarce funds grow, better evidence is needed to show that agricultural research generates attractive rates of return compared to alternative investment opportunities. The result has been an upsurge in studies, seeking credible ex-ante estimates of the expected benefits of current and proposed research programs and ex-post estimates of benefits from previously performed research (Smith and Pardey; Morris and Heisey). Research managers also feel increased pressure to direct publicly funded agricultural research toward the needs of small-scale farmers and the rural poor. Policy makers are calling on research managers to explicitly consider poverty reduction objectives when making resource allocations (Byerlee; Alwang and Siegel).

Despite this increased interest, few ex-ante studies of impacts of agricultural research on the poor have been conducted. Widely used ex-ante assessment tools such as economic surplus analysis (see Alston, et al.) can be disaggregated by region and for population subgroups to examine the distribution of research impacts on population sub-groups. For example, Mills, and Mutangadura and Norton disaggregate research-induced surplus change by region and farm type, respectively. Both studies found that impacts vary substantially by regional and farmer characteristics. Karanja, Renkow and Crawford found that returns to agricultural research varied substantially in Kenya according to ecological conditions and that maize research appropriate for high-potential areas has the largest aggregate impact on surplus.

All these findings support the notion that benefits of research are unevenly distributed and that concerns for distributional outcomes should be included during funding and priority-setting exercises. Impacts on household-level and aggregate poverty are considerably more difficult to measure or predict, primarily because poverty status is household-specific while most surplus measurement is conducted at the market level. In an ex-ante setting, research-induced shifts in the aggregate supply function lead to market-level surplus changes; such shifts are caused by decisions made by individual farmers to adopt and the subsequent impact on their marginal cost of production. The market surplus approach requires, among other things, estimates of technology adoption, which may vary by region, by household conditions and other factors (Mills, et al.)

This paper presents and applies a simple procedure for reconciling market-level surplus changes with income gains on individual farms. Farm-level information is used to measure levels of and changes in income associated with adoption of a new technology. Associated changes in poverty are computed measures of the Foster-Greer-Thorbecke (FGT) type. Calculations of income changes at the farm level are aggregated to the market level and reconciled with market-level calculations of surplus changes using standard techniques.

Agricultural research and poverty

Agricultural research can have important impacts on levels and the distribution of income and can reduce poverty in a number of ways. Technology adoption lowers per unit costs of production, increases the supply of food products and can raise incomes of adopting producers. Outward shifts in supply can lower food prices depending on the elasticity of demand. Depending on the input bias of the technical change, demands for inputs may be affected. Increased labor demand may raise wages and the earnings of poor laborers. The poor often have little land or capital, so they gain disproportionately from employment generated by agricultural growth. They also gain disproportionately as consumers from lower food prices, since they spend most of their incomes on food (Thirtle, et al.). Technological changes may bring new cropping patterns whose characteristics are difficult to predict. Higher productivity could also create broad-based multiplier effects within the rural community inducing employment creation in industries related to the crop, such as value-added processing, and roadside marketing.

Methods and data

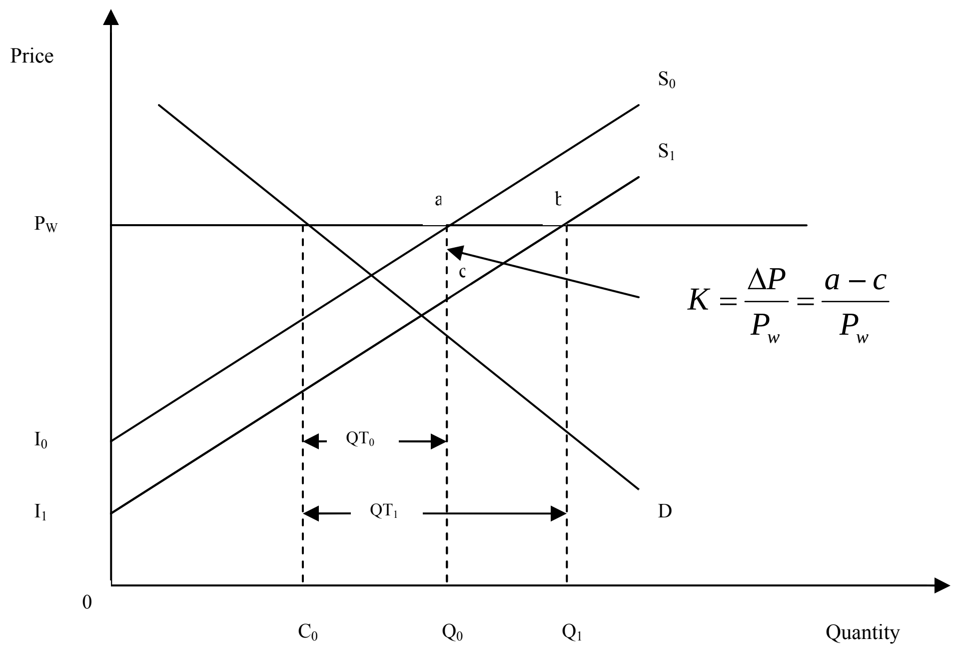
We combine economic surplus analysis with household-level data to construct ex-ante estimates of changes in poverty resulting from predicted adoption of virus-resistant peanut varieties. The surplus analysis provides estimates of changes in prices and total economic surplus under different scenarios about rates of adoption. The household-level analysis uses information about changes in cost of production associated with adoption to infer household-specific changes in income following adoption. This same information is embedded in the surplus analysis. Predicted rates of technology adoption are used to identify households for whom incomes will change. With appropriate survey weights, the household level income changes can be used to estimate changes in aggregate poverty and changes in aggregate income, which, in the context of the model, should be consistent with findings from the market-based surplus analysis.

Standard approaches to ex-ante estimation of research impacts involve several steps: (i) calculation of a k-shift representing the unit-cost reduction associated with use of a new technology; (ii) gathering information on expected adopted rates and their evolution over time; (iii) combining (i) & (ii) with market-related information on supply and demand elasticities and equilibrium prices and quantities (Alston, et al.). These steps allow estimation of price, quantity and corresponding surplus changes associated with technology adoption. Modifications to these techniques include efforts to distinguish between different producer groups, who may vary in propensity to adopt or use different technologies (Mutangadura and Norton), regional variation to reflect spatial differences in cost, shipping, prices and markets (Mills), and regional differences in productivity (Karanja, Renkow and Crawford).

Consider, for example, changes in economic surplus calculated using a small open economy model. The small open-economy assumption implies that the primary beneficiaries are the peanut producers, either through sales or home consumption. The initial equilibrium is defined by consumption, C_0, and production Q_0, at the world market price, P_W, with export quantity QT_0 equal to the difference between consumption and production (figure 1). Research lowers the unit cost of production and causes supply to shift from S_0 to S_1 and production to increase to Q_1. As a result, exports increase to QT_1. Economic surplus change is equivalent to producer surplus change and is equal to area I_0abI_1. If prices in all other markets (for example, labor markets) are unaffected by the shift in supply, then the surplus change captures the entire short-run benefits of adoption.

In cases where other prices change, additional analysis is needed; a multi-market model is one example of such an analysis (Karanja, Renkow and Crawford). If the price of the product in question changes, due to a less than infinitely elastic demand, then changes in consumer surplus must be computed as well.

Figure 1: Research benefits in a small open economy



$$K = \frac{\Delta P}{P_w} = \frac{a-c}{P_w}$$

Analyses of predicted changes in poverty resulting from adoption of a new technology involve three main steps: (i) computing the household-level value of the welfare measure (income or consumption per capita) and comparing it to the poverty line; (ii) determining which households are most likely to adopt the technology and estimating how household welfare will change following adoption; and (iii) adding up the change in the number of poor people or households resulting from adoption. Due to problems of measurement and seasonality in income generation in agriculture, consumption is frequently preferred to income as a measure of well being (Deaton). However, since our focus is on adoption-induced changes in farm income and we have good measurements from an entire growing season (see below), we rely on income per capita as our measure of well-being. The household analysis of ex-ante income changes among adopting households can be used to create an estimate of market surplus changes (corresponding to the total change in income for all participants in the market) and of changes in poverty in the population.

The FGT indices are a commonly used means to add up poverty in a population and are useful because they are additively decomposable with population share weights (Ravallion). Additive decomposability allows evaluation of impacts of agricultural and other government policies on sub-groups (such as peanut producers). The FGT class of poverty measures is defined as $P_\alpha = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z-y_i}{z}\right]^\alpha$, where n is the total number of people, q is the number of poor people, y_i is income or expenditure of the i^{th} poor household, z is the poverty line, measured in the same units as y, and α is a parameter of inequality aversion. When $\alpha = 0$, P_α is the headcount index, or the proportion of the population that is poor. When $\alpha = 1$, P_α is the poverty gap index, a measure of depth of poverty. The depth measure is based on the aggregate poverty deficit of the poor relative to the poverty line. When $\alpha = 2$, P_α is a measure of severity of poverty, and reflects the degree of inequality among the poor. Each α tells the analyst different things about the patterns of poverty in a population and allows comparison of policies. FGT indices are now a standard part of virtually all poverty assessments and used as inputs into poverty reduction strategies around the developing world.

Survey data on household production and income will allow estimation of poverty rates, but the study seeks to understand how adoption of a new technology will change poverty rates. The correspondence between the economic surplus approach and the household approach comes from the change in marginal (unit) cost of production caused by adoption of the technology. Farm profits for the i[th] household are given by:

$$(1) \qquad \pi_i(\tau) = PX_i - \int_0^{X_i} C_i^{'}(X,\tau)dX$$

Where τ is a technology shifter, PX_i represents revenues and the right-hand integral is the variable costs of production (C'(X, τ) is the marginal cost function). Adoption of the technology causes profits to shift by

$$(2) \qquad d\pi_i(\tau)\Big/d\tau = P\frac{\partial X_i}{\partial \tau} - \int_0^{X_i} \frac{\partial C_i^{'}(X,\tau)}{\partial \tau}dX - C_i^{'}(X_i)\frac{\partial X(\tau)}{\partial \tau}$$

where Leibnitz' rule is used to compute the derivative in (2). The change in profits in equation 2 is equivalent to the surplus (I_0abI_1) in figure 1 in a single-producer economy. To see this, note that the first term on the right-hand-side of (2) is equal to abQ_1Q_0 in figure 1. The second term is acI_1I_0, and the third term approximates cbQ_0Q_1 for small changes. Summing over the total number of producers in the region leads to equivalence between the measure of change in individual farmers' profits in equation 2 and the area of surplus change in figure 1.

The change in peanut production and household income from direct production of peanuts as a result of agricultural research is related to the value of agricultural production before adoption of the new technology, and the per unit cost reduction that results from adoption. The same k-shift as used in the surplus analysis can also be used at the household level to approximate $d\pi_i(\tau)$. For the i[th] household, the change in surplus (income) is

$$(3) \qquad d\pi_i(\tau) \approx K_i P_i Q_i \left(1 + 0.5 K_i \varepsilon\right) = I_0 ab I_1,$$

where P_i is the pre-research price, Q_i is the pre-research quantity, ε is the elasticity of supply, and K_i is the proportionate shift downward in the marginal cost curve due to research. Adopters of the technology receive this income benefit; the market K-shift shown in figure 1 incorporates assumptions about rates of technology adoption. In cases where indirect effects (labor market, consumer prices) are important, estimates of income changes due to wage changes (producer surplus in the labor market) and consumer price changes (consumer surplus in the product markets) should be allocated to individual households with members who participate in the labor market and purchase the good in question.

Since we desire ex-ante predictions of poverty change, it is necessary to identify farmers who are likely to adopt hybrid or improved varieties in order to implement equation (3). We suggest estimation of a model of adoption probabilities to identify households most likely to adopt the new technology. For example, farm decision makers face two alternatives—adopt or not, with the decision based on expected profits associated with each alternative, perceptions about risks, availability of information, and household-specific constraints. With such a model—a probit model, for example-- the probability of adoption can be predicted, given observations on the adoption of similar technologies and variables affecting the probability of adoption. Households can then be ranked in order of decreasing probability of adoption and "adopting households" can be identified as those whose predicted probability of adoption exceeds a threshold prediction probability. If we assume that 30 percent of households adopt, we select those households whose predicted probability of adoption exceeds that of the household at the 70th percentile of our ranking.

In an ex-ante setting, no information is available on adoption of the specific technology of interest. The adoption probability index can be estimated using observations on adoption of an observed alternate technology, such as hybrid seed or fertilizer. The assumption is that past adoption propensities are good indicators of those households most likely to adopt the technology in question.

Data and Results

Results are presented in two main sections. The first section presents the economic surplus model results; the second identifies farmers most likely to adopt a new technology using hybrid seed as a proxy and then presents the impact of adoption of rosette resistant seed varieties on household income changes and poverty. The study was conducted in Eastern Province, Uganda. Data for calculation of poverty indices and the adoption model were obtained from a national household survey conducted by the International Food Policy Research Institute (IFPRI), in collaboration with the Uganda Bureau of Statistics (UBoS) through the Uganda National Household Survey (UNHS) project of 1999/2000. The data set is extensive (including 2949 households in the peanut growing region), enabling computation of the poverty indices and providing information on other socio-economic characteristics affecting technology adoption. A crop survey, a socio economic survey and community survey questionnaires were all included. Information was obtained on household demographics, assets, labor allocation, yields and costs and other agricultural production information. The project targeted representative households across Uganda. (Uganda National Household Survey)

Economic surplus estimation

Data on expected yield and cost changes following adoption of the Rosette-resistant technology, together with expected adoption rates were obtained during a visit to Uganda during July and August, 2003. One breeder, responsible for the groundnut improvement program in the whole of Uganda, two extension workers, one a district extension officer in charge of Soroti District (Eastern Province), a farm management specialist, and groups of farmers were interviewed in the field. University scientists who carried out groundnut improvement research and representatives of buyers and processors of groundnuts were also interviewed. A questionnaire was designed and targeted mainly at research managers, breeders, and extension agents who interact with farmers on a regular basis. Among other items, the questionnaire measured research expenditures for the lifetime of the CRSP in Uganda, and elicited information on adoption profiles, yield changes and costs of production. The adoption, yield, and cost data were used to compute the K-shift.

This information was collected for current peanut yields and costs of production for traditional and virus-resistant varieties (Serenut 3 and 4) as well as realized and projected adoption rates. The varieties were released in 2001 and therefore there has already been some adoption (15 percent in the first two years) and higher adoption is expected over the next few years (up to 50 percent). The Ugandan National Agricultural Research Organization (NARO) had been conducting research on Groundnut Rosette

Virus (GRV) for several years when the Peanut CRSP came on board in May 2001 to supplement ongoing research and bringing material developed by ICRISAT in Malawi. This analysis estimates changes in economic surplus for a fifteen year period starting from inception of Peanut CRSP activities in May 2001 through 2015.

Supply and demand elasticities

Many studies have examined the responsiveness of supply to changes in prices for a variety of crops (e.g. Askari and Cummings; Tsakok; and Rao). Although none of these studies investigated peanut supply in Uganda, they provide useful guidelines for the current study. Rao states, for example, that crop-specific acreage elasticities range between zero and 0.8 in the short run while long-run elasticities tend to be slightly higher (between 0.3 and 1.2). Yield responses to price are smaller and display much less stability than acreage elasticities. Askari and Cummings emphasize the degree of variation in quality of elasticity estimates presented in studies of supply responsiveness.

Economic theory suggests that agricultural commodities using relatively little land and few other specialized factors tend to have relatively high elasticities of supply, as adjustments to price changes are less costly. Peanuts in Uganda are mostly grown on small plots by poor farmers using limited resources, mainly with only seed and labor costs. It is therefore easy to increase or decrease production in the short run in response to changing prices. Alston et al propose that in the absence of adequate information, a supply elasticity of 1 is a good starting point since long-run elasticities for most agricultural commodities are greater than one, while short-run and intermediate elasticities are usually close to one. The elasticity of demand is assumed to be infinite because Ugandan production is small on a global market scale and the Ugandan economy is relatively open. As a result of this assumption, the price does not change in response to technology adoption and all benefits are captured by producers[3]. Certain sub-regions might be characterized by less elastic demands due to transportation costs; extending the methodology to examine sub-regional impacts is straightforward.

Table 1: Costs of seed inputs in Eastern Uganda

Variety	Seed Cost US $/Kg
Serenut 1 (Hybrid)	1.50
Serenut 2 (Hybrid)	1.50
Serenut 3 (Hybrid)	3.00
Serenut 4 (Hybrid)	3.00
Local (Non-Hybrid)	0.80
Other Costs	**US $/Hectare**
Weeding	26.00
Planting	21.00
Chemicals (spraying)	17.00

Source: On-farm trial data and opinions of breeders and extension agents.
Note: hybrid varieties tend to cost more in the year of release when they tend to be initially scare. Over time, prices drop as seed multiplication increases. Serenut 1 and 2 were released earlier than Serenut 3 and 4. Hybrid seeds also require some chemical spraying, representing an additional cost. Increased yields also imply higher harvesting outlays.

Yield and cost change

Based on expert opinion of four Ugandan scientists and other experts of Serenut 3 and 4 peanut varieties, it is estimated that yields will increase by 67 percent following adoption

[3] Changes in prices imply changes in consumer surplus, which would make the poverty calculation more complex; in particular, household consumption data would be required, and the price change would affect outlays and the cost of living. The impact of peanut price changes on the overall cost of living will depend on the share of peanuts in expenditures of the poor.

of the new varieties (table 2). Column three of table 2 presents average peanut yields for Rosette-resistant varieties under normal farming conditions; the numbers in parenthesis are the maximum expected yields under experimental conditions, unlikely to be achieved by farmers. The expected yield change was expressed in a per-unit cost change (because the conversion requires dividing by the assumed elasticity of supply, or 1). Input use is expected to increase by 50 percent per hectare upon adopting the technology, mostly due to higher seed costs, but also to increased applications of chemicals.

This per hectare cost change was converted to a per ton cost change using the formula $K_t = \left[\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1+E(Y)}\right] pA_t(1-\delta_t)$ **(**Alston, et al., p. 380*)* and subtracted from the per unit cost change due to the yield change to arrive at a net per unit cost change of 37.1 percent.

Table 2: Estimated yield changes from adoption of resistant varieties in Eastern Uganda

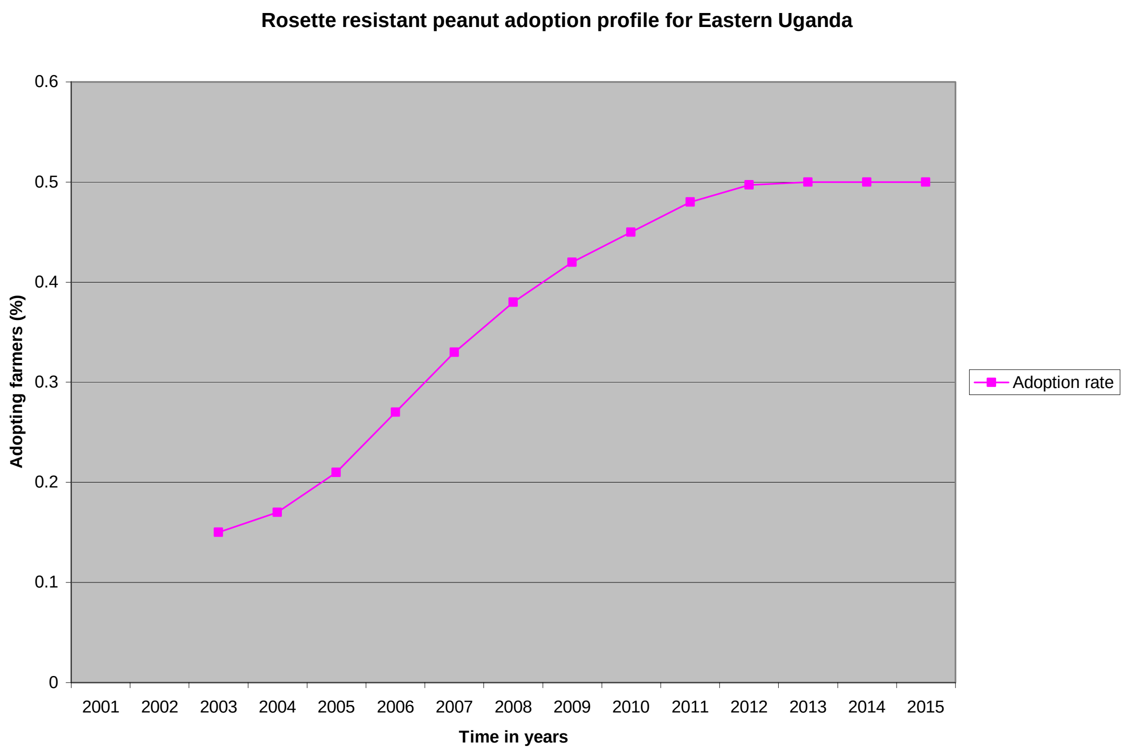
Variety	Average yield (Kg/ha) of non-rosette resistant varieties	Estimated yield (Kg/ha) of rosette resistant varieties on farm	Percent yield change
Serenut 3	800	1374 (2747)	71.75
Serenut 4	800	1298 (2494)	62.25
Average			67.00

Source: On farm trial data and opinions of breeders

Aggregate adoption for purposes of computing surplus changes

The aggregate market surplus calculation requires use of a predicted rate of adoption of the new variety. Extension workers were asked to estimate rates of adoption. Fifteen percent of farmers were estimated to be currently using Rosette-resistant varieties. For subsequent years, we project adoption, which is expected to reach a maximum of 50 percent after nine years (figure 2).

Figure 2: Rosette-resistant peanut adoption profile for Eastern Uganda



Source: Predictions based on interviews with extension agents.

Price and Quantity

A three-year average border price for 1999 to 2001 was used as the base price in the economic surplus model. Based on this average, a ton of peanuts was valued at $750 in 2001, the time of inception of the Peanut CRSP project. Quantity produced refers to production volumes specific to the part of the country (Eastern Province) where the evaluation is carried out. Between the 1999 and 2001 agricultural seasons, Eastern Province districts produced an average of 47 thousand tons of peanuts (Uganda National

Household Survey). This quantity is used as the base quantity in the estimation. Quantity is also assumed to have an exogenous growth rate of one percent per year, irrespective of adoption of new varieties.

Research cost

USAID, through the Peanut CRSP, will have contributed approximately $56,000 to the project by September 2004. This amount represents only part of the costs. Other costs were incurred by the public sector in Uganda, by ICRISAT in Malawi, and by the University of Georgia. Looking at it from USAID/Uganda perspective, a 20 percent adjustment was made to account for cash inflows from other Ugandan sources, for example to cover salaries of breeders and other costs. The total cost (Ugandan plus USAID) is estimated to be about $67,120 or $16,780 per annum, for the four-year period (2001-2004) in which the research was carried out. Other costs incurred by ICRISAT and Georgia are not considered when calculating returns on the USAID/Uganda investment.

Aggregate changes in net economic benefits

The net present value of the research over the 15-year period is estimated to be $US 51.6 million, $42.6 million and $35.4 million at 3, 5, and 7 percent discount rates respectively. These estimates represent aggregate net returns to producing households in Eastern Region, under the model assumptions and the projected adoption profile shown in figure 2. These estimates do not, however, show how poverty will change as a result of the research. Changes in poverty clearly depend on the characteristics of adopting households along with the per-household change in income due to adoption. Such an analysis requires a focus on specific households in the region.

Household-level incomes and changes in poverty

Poverty in Eastern Province is alarmingly high and the depth and severity indices show high degrees of shortfall in income below the poverty line and a high degree of inequality among the poor. Members of peanut-producing households are less poor than those in the full sample; the headcount of poverty is about 4 percentage points lower compared to the full sample (table 3). The depth and severity indices indicate that peanut-producing households are more homogeneous than the full sample, as the percentage point gap between peanut producers and the full sample is higher for the depth and severity indices compared to the headcount index. Poverty is much deeper and more severe among the non-producing households than the headcount index alone indicates.

Table 3: Base poverty indices for peanut-producing and all households

	Peanut Producers (PP)	All sample (AS)
Poverty Index		
Headcount	0.7084	0.7456
Depth	0.3286	0.3894
Severity	0.1896	0.2454

Source: own computation using Uganda National Household Survey (1999-2000).

Using equation 3 and the K-shift from the surplus analysis, the change in income for adopting households can be approximated as:

$$d\,\pi_i\,(\tau) = K*P*Q_i*(1+0.5*K*\varepsilon)$$

$=0.371*P*Q_i*(1+0.5*0.371)$

$= 0.44*P*Q_i$,

or a 44 percent increase over the base value of peanut production. Post-adoption household income for adopters is $y_i*=y_i^0 + d\ \pi_i\ (\tau)$, where y_i^0 is initial (total household) income. This post-adoption income is compared to the poverty line and the change in the FGT poverty index resulting from adoption is computed. The challenge is to identify those farmers most likely to adopt the resistant technologies.

Determinants of adoption of new technologies

All 2949 Eastern Province households in the sample were asked in the crop survey questionnaire about use of hybrid or improved maize seed; 2059 of these produce maize. Table 4 shows summary statistics for adopting and non-adopting households. Fewer households (499) reported using hybrid or improved seed compared to non-users (1560). Non-adopting households were headed by slightly older people, had fewer members, and lower income per capita. Non-adopters were less likely to receive extension advice compared to their adopting counterparts. Adopters were mostly headed by males, who were married in 82 percent of the cases. Adopting households had more (27 percent) people with some form of post secondary education (university education included) than non-adopting households (14 percent). Most importantly, adopting households had more access to land and were more likely to receive information related to crop production and marketing.

We used a probit model to estimate the probability of adoption of new technologies, with the dependent variable representing use of hybrid or improved seeds and explanatory variables that included sex and age of household head, marital status, education, access to extension services and market information, land tenure, household size, income, land holdings and number of hoes owned. Results of the probit model are summarized in table 5.

Table 4: Characteristics of adopting and non-adopting households

Variable name	Description	Adopters (N=499)		Non-adopters (N=1560)	
		Mean	SD	Mean	SD
Age	Age of household head (years)	43.2	15.5	45.3	16.6
Household size	Number of people normally residing	6.4	3.7	5.5	3.3
Income	Income per capita (US $)	165.0	163.0	127.0	160.0
Land holding	Land owned per capita (Hectares)	2.9	4.4	2.9	3.9
Nohoes	Number of hoes	4.0	2.7	3.1	2.1
Extension	Extension advice (=1 indicates household received extension advice in 1998	0.6	1.4	0.2	0.8
		N	**%**	**N**	**%**
Male-headed	Male household head	85.6		1144	73.3
Marital Status	Married household head	82.0		1142	73
	Highest level of education				
	-Primary	261	53.3	844	54.1
Edjunior	-Junior	20	4.0	43	2.8
Edsecondary	- Secondary and beyond	135	27.05	224	14.36
	Land tenure				
Freehold	-Freehold	302	60.5	738	47.3
	-Customary	160	32.0	745	47.8
Market	Market information received in 1998	222	44.5	498	32

Source: Uganda National Household Survey (1999-2000). Exchange rate $1:UGS1900

The signs for most coefficients are consistent with expectations and economic theory. For example, a positive relationship is expected between adoption of new technologies and level of education, access to information, income, and ownership of production resources. The older the household head, the less likely he or she is to adopt hybrid or improved seed as shown by a negative sign on the estimated coefficients. This is based on using a square of the age in the probit model. Marital status has a negative sign as well, meaning that married household heads are less likely to adopt the hybrid technology, but the variable is not statistically significant.

Table 5: Summary of the probit results: dependent variable = 1 (for adopters), 0 (otherwise)

Parameter	Estimate	Marginal Effect	Standard Error	Chi-square
Intercept	-2.9177		0.4291	46.240
Male-headed	0.3107	0.0873	0.0949	10.71000
Age				
Age Square	-0.0001	-0.0000	0.0000	5.8700
Marital Status	-0.0908	-0.0277	0.1003	0.8200
Edjunior	0.2451	0.0796	0.1744	1.9700
Edsecondary	0.2864	0.0916	0.0821	12.1600
Extension	0.1464	0.0440	0.0304	23.2800
Market	0.1918	0.0588	0.0667	8.2700
Land Holding	0.0306	0.0092	0.0333	0.8400
Freehold	0.2824	0.0845	0.0645	19.1800
Household Size	0.0264	0.0079	0.0749	0.1200
Income	0.1217	0.0365	0.0330	13.5900
Nohoes	0.2661	0.0799	0.0704	14.2800

N = 2059; Max-rescaled R-Square = 0.1278; Log-likelihood = -1048.13. Marginal effect refers to the marginal measured effect of the variable on the probability of adoption

Male-headed households are about 9 percent more likely to adopt hybrid or improved seed than female headed households. Education has a strong impact on technology adoption: households with junior high school as the highest education and those with secondary or higher are 8 and 9 percent, respectively, more likely to adopt than those households who have primary education as their highest education level achieved. An increase in the age of the household head by 1 year results in the probability of adoption declining by 0.13 percent. An increase in per capita income results in a significant but small increase in the probability of adoption by $1.056*10^{-4}$ %.

Impacts of adoption of the improved peanut variety on aggregate poverty

The probit results are used to create an index of likelihood of adoption of new technologies, and households are ordered by this index. We then apply the income changes from the new technology to the first 15 percent, 30 percent and 50 percent of the peanut-producing sample according to each individual household's adoption probability. As noted above, for all adopting households, income grows by 44 percent of their base value of peanut production (including own consumed peanuts). This income is added to other income to determine poverty status and compute the poverty index[4]. Note that as the adoption rate increases, more low-income producers are assumed to adopt, and therefore the mean household income of adopters falls (table 6). This result is a direct consequence of our adoption model; predicted adoption rates grow with household income (table 4). The non-adopters have lower incomes, but correspondingly smaller

[4] Due to lack of consensus about an income-measured poverty line in Uganda, we used a poverty line equal to $0.75 per person per day. Although this line is low by international standards (the World Bank standard is $1 per person per day), international standards tend to refer to consumption poverty and measured consumption is usually significantly higher than income. The poverty line can be adjusted accordingly as consensus about an income poverty line is attained.

family sizes. Adoption of the technology leads to only a modest increase (between 5 and 6 percent) in household incomes. Among peanut-producing households, peanut income represents about 20 percent of total household income.

Table 6: Household income before and after adoption

	Percent of households adopting		
	15 %	30 %	50 %
Household Income (US$)[5]			
Before adoption	2,056	1,660	1,351
After adoption	2,156	1,753	1,435
Household size of adopters	*8.48*	*7.99*	*7.35*
Income of Non-adopters	930	850	767.00
Household size of non-adopters	*5.85*	*5.50*	*5.15*

Source: Own computation using Uganda National Household Survey (1999-2000) and results from table 5.

All three poverty indexes fall modestly as a result of technology adoption (table 7). If all peanut producers in the region were to adopt the new varieties, under our assumptions about yield and cost changes, the poverty headcount among adopting households would fall by about 4 percentage points. The poverty gap and severity indices also fall following adoption. The poverty severity index falls by 2 percentage points with full adoption (from .1896 to .1716), representing a 10.5 percent decline in the poverty severity. As predicted adoption rates increase, the poverty indices also increase; because incomes are positively associated with adoption, mean household income falls as the predicted adoption rate increases. Since the poverty gap and severity indices fall as adoption increases, a number of households are moved closer to the poverty line and

[5] The exchange rate between the US$ and the Ugandan Shilling was $1: UGX1900 in August 2003.

there is less inequality among poor households. Both these factors further highlight the poverty-reduction benefits of the new Rosette-resistant peanut seed.

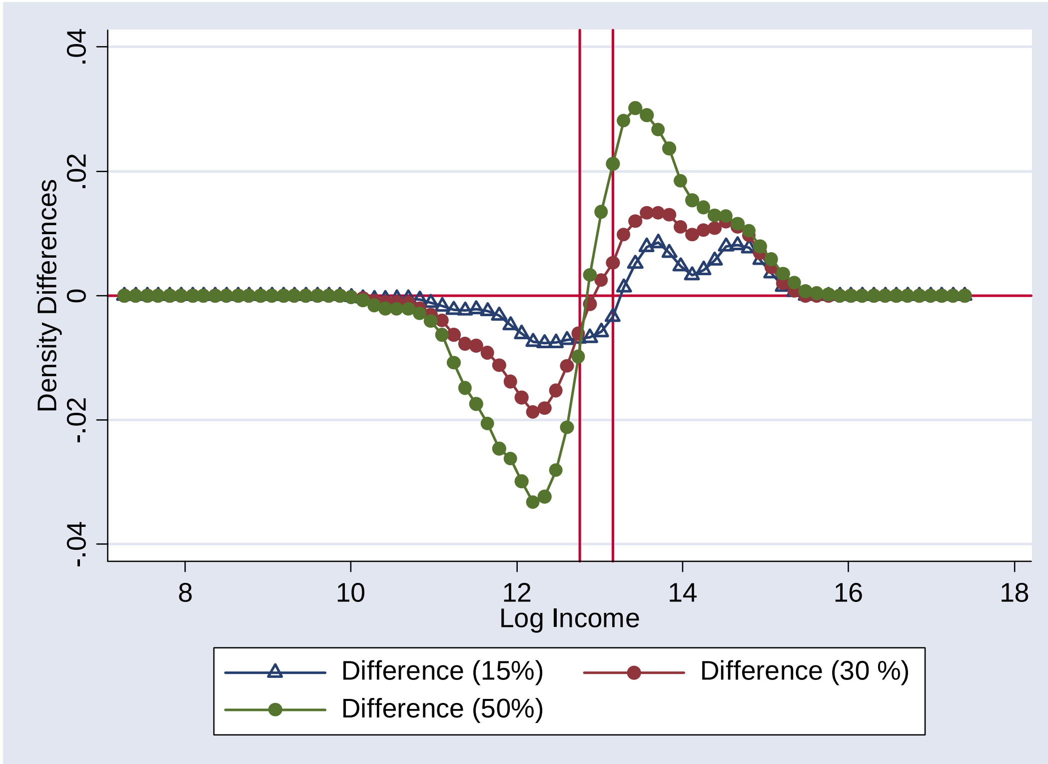
Table 7: Poverty indices for peanut-producing and all sample households, various adoption rates

Adoption	0%	0%	15%		30%		50%		100%	
	Peanut Producers (PP)	All sample (AS)	P P	AS	PP	AS	PP	AS	PP	**AS**
Poverty Index										
Headcount	0.7084	0.7456	0.7028	0.7442	0.6955	0.7424	0.6875	0.7404	0.6710	0.7363
Depth	0.3286	0.3894	0.3265	0.3888	0.3216	0.3876	0.3169	0.3864	0.3025	0.3828
Severity	0.1896	0.2454	0.1882	0.2451	0.1856	0.2444	0.1826	0.2437	0.1716	0.2409

Source: Own computation using Uganda National Household Survey (1999-2000) and results from table 4.

The different assumptions about adoption rates have subtle effects on the distribution of household income. These differences are illustrated in figure 2, which shows the base density of income for peanut farmers subtracted from the density of income at different levels of adoption (a negative density difference implies that the post-shift distribution has relatively fewer households along that range). At the 15 percent level of adoption, the income distribution shifts slightly to the right, but the shift occurs very close to the $.5 per day (the left-hand vertical line) and above it. Few households at the very low end (left-hand tail) of the income distribution see their incomes grow as a result of adoption. At higher rates of adoption, the increase in income at very low levels of income becomes more pronounced. Higher rates of adoption imply bigger density shifts and higher impacts on low-income farmers.

Figure 2: Income density differences, base density subtracted from densities following different levels of adoption.



Source: Own computation using Uganda National Household Survey (1999-2000)

Our analysis of household-specific adoption rates hints that there will be a difference in the aggregate surplus change derived from the household analysis and that predicted by the market model. The reason for this discrepancy is that the market model assumes that adoption is independent of income and farm size. The aggregate surplus change at the 15 percent adoption rate assumes that 15 percent of the total base quantity of output is subject to the yield increase, while the household analysis shows that the first 15 percent of adopters are likely to be wealthier and have more land available than others. Thus, the household analysis shows that at lower rates of adoption, the economic surplus model is likely to understate the aggregate impact of technology adoption on income change (table 8). At very high rates of adoption, the difference between the surplus estimate and that derived from the household analysis gradually disappears.

Table 8: Income changes from aggregate surplus analysis vs household level changes (in $ US)

Adoption Rate	15%	30%	50%	100%
Income change (economic surplus model)	1,835,000	3,768,000	6,501,000	14,105,000
Income change (household analysis)	3,173,000	5,874,000	8,218,000	14,466,000
Difference	-1,338,000	-2,106,000	-1,717,000	-361,000

While the impact on aggregate poverty reduction is rather modest, we are examining a single agricultural technology and have not accounted for dynamic effects, such as increased acreage devoted to peanuts, impacts on consumer prices (which we assume to be zero) and labor market effects. The impact of the new Rosette-resistant variety on demand for labor is likely to be minimal and given a situation with high levels of seasonal underemployment, the labor market effects will be small at best. Over time, modest increases in incomes may lead to increased investments in household assets, leading to poverty-reducing growth effects.

Conclusion

Results indicate that sizable research benefits are generated by adopting Rosette-resistant seed varieties and that they accrue mostly to farmers as there is no price effect in the model. These benefits are estimated to be $47 million, $38.8 million and $32.3 million at the 3 percent, 5 percent and 7 percent discount rates respectively. The poverty indices show modest changes in poverty, reflecting the fact that these surplus changes are distributed among a large number of peanut-producing households, many of whom are not poor. As adoption rates increase, poverty reduction grows, because the poor are, in general less likely to adopt new technologies as the non poor. The depth and severity indices also fall with adoption showing that more households are drawn closer to the poverty lines (and hence escaping poverty) as a result of adoption. Results show that to increase the impact of low-cost technologies such as new disease-resistant varieties, special efforts should be made to promote adoption among lower-income producers.

The methods employed here can easily be adopted to other cases where policy makers wish to have ex-ante information on agricultural research's impact on poverty reduction.

References

Alston, J.M., Norton, G.W., Pardey, P.G. *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting.* (Ithaca, NY: Cornell University Press, 1995).

Alwang, J., Siegel, P.B. Measuring the Impacts of Agricultural Research on Poverty Reduction. *Agricultural Economics* 29 (2003): 1-14.

Askari, H. and J. Cummings. *Agricultural Supply Response: A Survey of Econometric Evidence* (New York: Praeger, 1977).

Byerlee, D. Targeting Poverty Alleviation in Priority Setting for Agricultural Research. Food Policy 25 (2000): 429-445.

Foster, J., Greer, J., Thorbecke, E. "A Class of Decomposable Poverty Measures." *Econometrica,* Vol. 52 No. 3 (1984): 761-766.

Gibbons, R.W. . "Disease, Pests and Weeds in Tropical Crops: Groundnut Rosette Virus." Pp.. 19-21 in: *Diseases of Tropical Crops*. J. Cranz, J Schutter, and W. Koch, (eds.) (Berlin: Verlag Paul Parey, 1977).

Hazell, P., Haddad, L. "Agricultural Research and Poverty Reduction, Food, Agriculture, and the Environment." Discussion paper 34, IFPRI/Technical Advisory Committee of the CGIAR, Washington DC 2001.

International Crop Research Institute for Semi-Arid Tropics (ICRISAT) website: Management of Groundnut Rosette: Past, Present, and Future http://www.icrisat.org/text/research/grep/homepage/grephomepage/archives/rosette.html

Karanja, D.D., Renkow, M. and Crawford, E. "Welfare Effects of Maize Technologies in Marginal and High Potential Regions of Kenya," *Agricultural Economics* v29, n3 (Special Issue Dec. 2003): 331-41

Mills, B. F. Ex-ante Agricultural Research Evaluation with Site Specific Technology Generation: The Case of Sorghum in Kenya. *Agricultural Economics* 16 (1997) 125-138.

Morris, M.L., Heisey, P.W. "Estimating the Benefits of Plant Breeding Research: Methodical Issues and Practical Challenges." *Agricultural Economics,* 29 (2003):241-252.

Mutangadura G., Norton G.W. Agricultural Research priority Setting Under Multiple Objectives: An Example From Zimbabwe. *Agricultural Economics* 20 (1999):277-286.

Rao, J.M. "Agricultural Supply Response: A Survey." *Agricultural Economics* 3 (1989): 1-22.

Smith, V.H., Pardey, P.G.. "Sizing Up Social Science Research (Measuring the Benefits of Social Science Research)." *American Journal of Agricultural Economics* 79: 5 (2003): 1530-1534.

Thirtle, C., Lin L., Piesse, J. "Impact of Research Led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia and Latin America. *World Development*, 31: 12 (2003): 1959-1975.

Tsakok, I. *Agricultural Price Policy: A practitioner's Guide to Partial Equilibrium Analysis*. (Ithaca, NY: Cornell University Press, 1990).

Uganda National Household Survey (1999-2000). Uganda Bureau of Statistics, Ministry of Finance, Planning and Economic Development.

World Bank (2003). Uganda Country Brief, taken from the World Bank website (http://www.worldbank.org/ug/ctry_brief.htm)

World Fact Book (2003). The World Fact Book: Uganda http://www.cia.gov/cia/publications/factbook/geos/ug.html

World Bank (1996). *Uganda: The Challenge of Growth and Poverty Reduction*. The World Bank, Washington, D.C.