CROP PROTECTION PROGRAMME

GROUNDNUT ROSETTE DISEASE MANAGEMENT

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FINAL TECHNICAL REPORT

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Acronyms and abbreviations

ADC	Agribusiness Development Centre
AFLP	Amplified fragment length polymorphism
ARC-GCI	Agricultural Research Council–Grain Crops Institute
AT	Appropriate Technology
BSA	bulk segregant analysis
DAP	days after planting
cDNA	complementary DNA
CORSU	Client-Oriented Research Support Unit
CPP	Crop Protection Programme
CRSP	Collaborative Research Support Programme (USAID funded)
DAO	District Agricultural Officer
DBIA	dot-blot immunobinding assay
DFID	Department for International Development (UK Government)
EA	East Africa
ELISA	enzyme-linked immunosorbent assay
FEW	Field extension worker
FAO	Food and Agricultural Organisation
FFS	Farmer Field School
GCI	Grain Crops Institute
GLM	Groundnut leaf miner
GRAV	Groundnut rosette assistor virus,
GRD	Groundnut rosette disease
GRV	Groundnut rosette virus
HEFCE	Higher Education Funding Council for England
HRI	Horticultural Research Institute
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDEA	Investment in Developing Export Agriculture
IPM	Integrated Pest Management
LC	Local commissioner
MAS	Marker assisted selection
NARES	National Agricultural Research Extension Services
NARO	National Agricultural Research Organisation
NASECO	Nalweyo Seed Company
NGO	Non-Governmental Organisation
NRI	Natural Resources Institute
NRInt	Natural Resources International
NTAE	non-traditional agricultural exports
PeMoV	peanut mottle virus
PStV	peanut stripe virus
RT-PCR	reverse transcription-polymerase chain reaction
SAARI	Serere Agricultural and Animal production Research Institute
SCRI	Scottish Crops Research Institute
SEA	southern and eastern African
SOCADIDO	Soroti Catholic Diocese Integrated Development Organisation
SSA	Sub-Saharan Africa
TOTs	Training of trainees
TPF	Technology Partnership Fund
USAID	United States Agency for International Development

Executive Summary

In the districts in northeastern Uganda where the 'Teso' system of agriculture is practised, groundnuts play a key role as a subsistence food source for poor people. Groundnuts are a valuable source of protein and oil and thus make a significant contribution to people's nutritional requirements. In addition, with a decline in the production of traditional cash crops such as cotton, groundnuts are now gaining increasing importance as a cash crop. Therefore, improved groundnut production methods have the capacity to enhance the livelihood opportunities of the rural poor. A 'needs assessment' exercise commissioned by the Department for International Development recognised this role for groundnut and identified some important production constraints. Groundnut rosette disease was found to be a major limiting factor and this project, which also builds on earlier research, was designed to help farmers to overcome this problem.

A large-scale household survey was conducted during the first year of the project and the findings were recorded in electronic format on a *database* that is being used by collaborating organisations. The survey identified that farmers consider several traits when selecting a groundnut variety, including drought resistance, duration, quality characteristics, yield and pest and disease resistance. These traits were all incorporated into breeding lines developed at ICRISAT and evaluated through the project in a comprehensive series of on-station and on-farm trials. This led to the *release of two new groundnut rosette-resistant varieties* in March 2002, *Serenut 3R and Serenut 4T* that will conform to the requirements of different local markets. The varieties are both short duration types, allowing two crops to be grown in a single year and thus greatly enhancing the income-earning opportunity of poor farmers.

The project has helped to lay the foundations for further crop improvement by *developing hybrid groundnut lines with multiple pest and disease resistance*; *providing training in breeding and evaluation methods for key staff*; *developing a practical method for evaluating vector resistance in groundnut*; *identifying molecular markers linked to a vector resistance gene and constructing a basic genetic linkage map for groundnut*. Thus capacity has been built in Uganda in the area of groundnut crop improvement, primarily through consolidating links between the National Agricultural Research Organisation and ICRISAT that will lay a sound basis for sustainable groundnut production. Knowledge gaps of farmers identified through the household survey have been addressed by the printing of a *groundnut production manual* that covers both pre- and post-harvest practices.

The project has ensured that the outputs will have large-scale impact by helping to *develop an effective system for seed multiplication and transfer*. This was achieved through the involvement of non-government organisations and the private sector and linking them to the formal government research and extension system. The success of this approach has led to the allocation of further donor support to facilitate the transfer of varieties between farmers. This will act to prime the system, which should then become self-sustaining.

In view of the successful outcome of the research in Uganda, it is planned to extend the approach to West Africa where serious groundnut rosette disease problems exist and there is the potential for substantial impact to be generated.

Background

Groundnut (*Arachis hypogaea* L.) is cultivated in the semi-arid tropical and sub-tropical regions of nearly 100 countries in six continents between 40° N and S of the equator. For people in many developing countries, groundnuts are the principal source of digestible protein (25-34%), cooking oil (44-56%), and vitamins. In many countries, groundnut cake and haulms (=dried foliage, stems) are used as livestock feed. Groundnut is also a significant source of cash income in developing countries that contributes significantly to livelihoods and food security and thus alleviates poverty. In many sub-Saharan Africa (SSA) countries, the crop is predominantly managed by women. Therefore, successful groundnut cultivation has a direct bearing on the overall economic and financial well being and nutritional status of women and children. As a legume, groundnuts improve soil fertility by fixing nitrogen and thereby increase productivity of other crops in the semi-arid cereal cropping systems. Groundnut requires little input, making it appropriate for cultivation in low-input agriculture by smallholding farmers. Groundnuts are grown in most of SSA by smallholder farmers as a subsistence crop under rain-fed conditions, either once or twice a year as in the case of the Teso farming system in eastern-central Uganda.

Groundnut rosette disease (GRD) was first reported in Tanzania in 1907 by Zimmermann and has since been reported from many countries throughout sub-Saharan Africa including Malawi, Nigeria and Uganda. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) estimates that GRD causes greater yield loss than any other virus disease affecting groundnut in the semi-arid tropics of the world. Frequent epidemics of groundnut rosette disease in SSA significantly reduce groundnut production and cripple the rural economy. In 1975, an epidemic in northern Nigeria destroyed approximately 0.7 million hectares (ha) of groundnuts with an estimated loss of $250 million (Yayock *et al.*, 1976). Recurrent epidemics have limited production to below the pre-1975 yields. Similarly, the epidemic that occurred in 1995 in eastern Zambia affected approximately 43,000 ha causing an estimated loss of $4.89 million. In the following year, in the central region of neighbouring Malawi, groundnut production was reduced 23% by groundnut rosette disease.

Scientists in Tanzania, Nigeria, Malawi and UK have studied aspects of GRD and their efforts have contributed enormously to our understanding of the problem (Naidu *et al* 1998).
In 1928, the vector was identified as *Aphis craccivora* by Storey and Bottomley in S.Africa and since then it has been established that:

- There are two forms of the disease, green rosette and chlorotic rosette, mainly distinguishable on the basis of symptoms (Hayes 1932, Smartt 1961, Hull and Adams 1968).
- Both forms are caused by a complex of two viruses and a satellite RNA (Hull and Adams 1968, Murant *et al.* 1988). Groundnut plants with rosette symptoms contain, groundnut rosette virus (GRV) which is transmitted by the aphid vector, but only from plants that also contain the second virus, groundnut rosette assistor virus, (GRAV) which itself causes no symptoms in groundnut. GRV supports the replication of satellite RNA and different variants of satellite RNA are responsible for the green and chlorotic forms of the disease (Murant and Kumar 1990).
- Cultural practices including early sowing and close spacing of rows reduce disease incidence (Evans 1954, Booker 1963, A'Brook 1964).
- Rosette resistance was identified in groundnut germplasm originating from West Africa (de Berchoux 1960, Gillier 1978). From this material, late maturing rosette resistant genotypes were developed (including RMP 12 and RG1). Few farmers have adopted these lines because they require a long growing season (150-180 days) to attain maturity making them sensitive to drought during the end of the season. They are also characterized by a spreading growth habit and small pods. In recent years efforts to transfer rosette resistance to short-duration types have been successful (Reddy and Subrahmanyam

1996) and several advanced groundnut breeding lines with high levels of rosette resistance, acceptable seed size and colour have been developed. Resistance in these genotypes and lines is to GRV and sat RNA but not to GRAV. To date no resistance to GRAV has been identified, but it would be a very useful character since it would reduce spread of the disease within the crop.

- Vector resistance was identified in groundnut genotype EC 36892, and this is another strategy that is currently being exploited in groundnut improvement breeding programs (Padgham *et al*. 1990a). The resistance factor in EC 36892 is located in the phloem tissue so that aphids initiate feeding but cannot maintain it (Padgham *et al.* 1990b). A rapid screening procedure to identify aphid resistance in this cultivar and populations of segregating lines using tannin analysis was developed (Grayer *et al.* 1992).

The previous phase of the DFID CPP project (R6811) made significant contributions with ICRISAT- Malawi in understanding vector-virus-host plant relationships associated with GRD and the identification of resistance mechanisms in other genotypes and cultivars. For example:

- The development of a new method to detect the three agents of the rosette disease complex (groundnut rosette assistor luteovirus (GRAV), groundnut rosette umbravirus (GRV) and satellite RNA (sat RNA) in groundnut and aphids by Reverse Transcription-Polymerase Chain Reaction (RT-PCR). This is the only test that can be used to detect all three agents of the disease in both plant and aphid material (Naidu *et al*. 1998)
- An improved understanding of the transmission efficiency of the three causal agents of rosette disease by the aphid vector on a range of groundnut genotypes including rosette-resistant and vector resistant lines under field and laboratory conditions. Separate infections with GRAV or with GRV plus sat RNA following aphid transmissions from plants infected with all three agents has previously been observed in laboratory tests (Murant, 1990). Results from the CPP project showed that separation of GRV and its sat RNA from the aphid-transmissible GRAV also occurs in nature and, as a result, expression of rosette disease symptoms in groundnut plants does not necessarily indicate the presence of GRAV. Although the number of plants varies in having either GRV and its sat RNA or GRAV alone or all three agents together, this separation has been consistently observed in different seasons and regions of Malawi. From the epidemiological point of view, diseased plants lacking GRAV remain 'dead ends' even though such plants contribute to yield loss. Similarly, symptomless plants containing only GRAV may play a negligible role in terms of spread of the disease. This separation will have a negative effect on the survival and perpetuation of GRV and its sat RNA in groundnut; nonetheless, GRV and sat RNA seem not to have any influence on this process since they are packaged in GRAV coat protein (Naidu *et al.* 1999).
- The identification of vector resistance in the early maturing, high yielding line ICG-12991 leading to low rosette incidence in field and laboratory trials. In rosette screening field trials, ICG-12991 has consistently shown lower disease incidence compared to another early-maturing groundnut cultivar, JL-24. Grafting of ICG-12991 (with infected scion from a susceptible cultivar) resulted in clear rosette symptoms and presence of GRAV. This suggested that ICG-12991 was susceptible to GRAV, GRV and sat RNA and that factors relating to aphid resistance may play a role in explaining low disease incidence and infection in the field.
- Aphid performance and feeding behaviour were measured on three groundnut cultivars, ICG 12991, JL-24 and GC7. The results showed that aphid survival was markedly lower on ICG-12991 than on the other cultivars and that aphids had difficulty in locating the phloem in the leaf tissue of ICG 12991. Aphids, however, had no difficulty in locating the phloem in flower stems on this cultivar which suggests that the resistance factor is associated with the non-phloem tissues in leaves. This is different to the mechanism in cultivar EC36892.

- In field trials the numbers of plants containing GRAV in ICG 12991, was lower than in other cultivars presumably because aphids could not inoculate GRAV into the phloem. An assessment of yield loss due to the aphid transmissible, groundnut rosette assistor virus (GRAV) was carried out with three other groundnut genotypes.

Although excellent progress was made in detecting the disease components, in understanding the field transmission of the disease complex and in identifying vector resistance in groundnut cultivars with good agronomic characteristics, farmers in Uganda have had little access to these improved lines.

In February 1998, DFID financed a needs assessment exercise in the Teso farming system, Uganda. Rosette disease was identified as the most important general or pest and disease problem on groundnuts both by farmers and Serere Agricultural and Animal production Research Institute (SAARI). Host-plant resistance is considered to be the most cost-effective management measure against rosette disease because farmers seldom adopt cultural or chemical control practices due to lack of resources, labour constraints, differing crop priorities and other factors. In the current project farmers and national scientists in the Teso farming system have evaluated groundnut lines (both early and medium maturing types) which have resistance to groundnut rosette virus or the aphid vector and provided feedback to the breeders on their performance. The strategic outputs from the earlier project, which focused on the mechanisms of resistance, have assisted in the development of breeding lines with combined resistance to both the rosette viruses and the aphid vector.

The current project has involved an adaptive, collaborative project between NRI, SAARI and ICRISAT, involving the development of farmer managed trials and an investigation into the potential for developing village/community seed banks to ensure adequate high quality seed is passed from one season to the next. ICRISAT and SAARI breeders and entomologists have been involved in developing improved characteristics based on Teso system farmers' needs and also the commercial requirements. The work has also led to the beginning of development of cultivars with multiple resistances (vector and virus resistance).

During the course of the project a new pest for the area, groundnut leaf miner, caused considerable damage to crops and insecticide control had to be used. Because this new constraint was expected to have an effect on the outcomes of the rosette management project the pest was identified and work on it was initiated.

Project Purpose

Semi-arid production system goal: Impact of significant pests on production from cereal (particularly sorghum) based systems minimised.

Semi-Arid production system output: Variability of economically significant viruses in cereal-based cropping systems and their interaction with vector species identified and incorporated into improved disease control strategies.

Groundnuts are associated with cereal-based cropping systems, either as intercrops or as a component of crop rotations. The earlier phase of the project contributed to the Programme Output, but rosette disease control strategies still needed to be developed with farmers and strengthened through the development of combined virus-vector mechanisms of resistance.

Groundnut varieties with resistance to either groundnut rosette virus or the aphid vector of rosette disease were identified in an earlier project phase. In this later phase, the social acceptability of these improved groundnut varieties and the economics of their production were considered. Also the single strategy of development and deployment of cultivars resistant to viruses alone is a risky proposition for a complex problem like groundnut rosette disease. Breeding efforts are needed to broaden the genetic base of resistance and to enhance its durability against different variants of groundnut rosette disease agents and vector. The strategic research in this phase has assisted in the development of early maturing groundnut varieties (90 to 110 days), with a potential for combined resistance to rosette viruses and the vector. These outputs will promote the sustainability of smallholder groundnut production in Uganda and contribute to the goal of sustaining rural livelihoods in the Teso farming system.

To this end the project has produced the following outputs:

Output 1 Groundnut production systems in research area understood (with specific reference to rosette disease).

Output 2 Groundnut varieties and germplasm lines tested under Teso farming conditions.

Output 3 Institutional capacity to improve groundnut production strengthened at SAARI.

Output 4 Mechanisms of resistance evaluated and determined in groundnut genotypes.

Output 5 Dissemination of outputs 1-4.

Output 6 Additional activities and outputs: identification and initiation of studies of groundnut leaf miner, a new pest to the Teso groundnut system.

Research Activities and Outputs

1.1 Socio-economic and rosette disease survey in ten sub-counties in the Soroti, Katakwi and Kumi Districts.

Introduction

The demand for new varieties of groundnut has its antecedents in a number of factors: (1) the impact of groundnut rosette virus disease on traditional and other newly introduced varieties, (2) the importance of groundnuts as a subsistence food source and increasing importance as a cash crop (with declines in other traditional cash crops such as cotton), (3) evolving biotic constraints (particularly the emergence of a ‘new’ pest (groundnut leaf miner), (4) the low multiplication factor of groundnut, and its impact on commercial seed multiplication profitability (and hence overall supply), and temporal demand issues (particularly short-term supply (shortfall issues). The survey questionnaire, designed in collaboration with the stakeholders and the statistician, reflected these concerns along with addressing other associated issues. The questionnaire is shown in Appendix 1. The results presented are based on 207 completed household questionnaires split across the 3 Teso districts of Soroti, Katakwi, and Kumi. There was multi-stage random household selection (moving through the administrative structural layers) along with purposeful selection of major groundnut growing areas (based on local advice). In the final stage households were selected at random from village lists with ten households per village.

In order to produce statistically significant results there was a target of 70 households per district[1]. The results can be compared between districts but offer the greatest precision at system level (the principal aim of the survey). The survey results were entered onto a database designed by the statistician and focus on both descriptive and analytical statistics.

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[1] There were 3 unusable returned forms (which were discounted from the analysis) making a total sample size of 207.

A copy of the database can be found on the CD provided with this report. The analytical statistics can be found in Appendices 2-15 and are listed at the end section 1.1.

Identified system constraints and coping strategies

The results in Table 1 indicate a number of constraints identified by farmers in the three districts. These clearly indicate that plant diseases and insect pests are critical constraints in this livelihood system[2]. Other constraints mentioned by farmers include drought and lack of quality seed – both of which were dealt with directly by the project. In general terms the constraints identified in Table 1 were consistent across the three districts (i.e. there was no significant variation).

Table 1 Identified system constraints

Constraint/Problem	Number of respondents identifying	% of all respondents
Plant diseases	201	97
Insect pests	187	90
Drought	179	86
Lack of quality seed	149	72
Labour shortages	137	66
Storage pests	130	63
Low/reduced soil fertility	115	56
Shortage of land	108	52
Low output prices	107	52
Land opening	83	40

Table 2 Indications of coping strategy shortfalls

Constraint/Problem	Number of respondents identifying	% of all respondents identifying who do not have a coping strategy
Plant diseases	201	44
Insect pests	187	45
Drought	179	94
Lack of quality seed	149	60
Labour shortages	137	29
Storage pests	130	39
Low/reduced soil fertility	115	53
Shortage of land	108	29
Low output prices	107	66
Land opening	83	27

Table 2 shows the proportion of surveyed households who have no coping strategy for the identified problems or constraints. It is apparent that a high proportion of households do not have coping strategies for the priority constraints that are being addressed by this project – a clear indication of a researchable constraint. The coping strategies that are related to insect pest and disease problems are associated with spraying and the removal of infected or infested material with very little else falling outside this. The majority of farmers who had a coping strategy used insecticide spraying.

[2] Groundnut producers were targeted specifically in the survey but virtually all farmers grow the crop in this region.

Farmers have quite detailed perceptions of rosette disease and leaf miner. They relate to knowledge[3] of the disease and/or pest, the extent of yield loss and the trend in its occurrence. In terms of rosette, 91.8 per cent of farmers knew about the disease; for leaf miner this was 79.7. Figure 1 highlights farmers' perceptions of yield loss.

Figure 1 Farmers perceptions of yield losses due to groundnut rosette and leaf miner

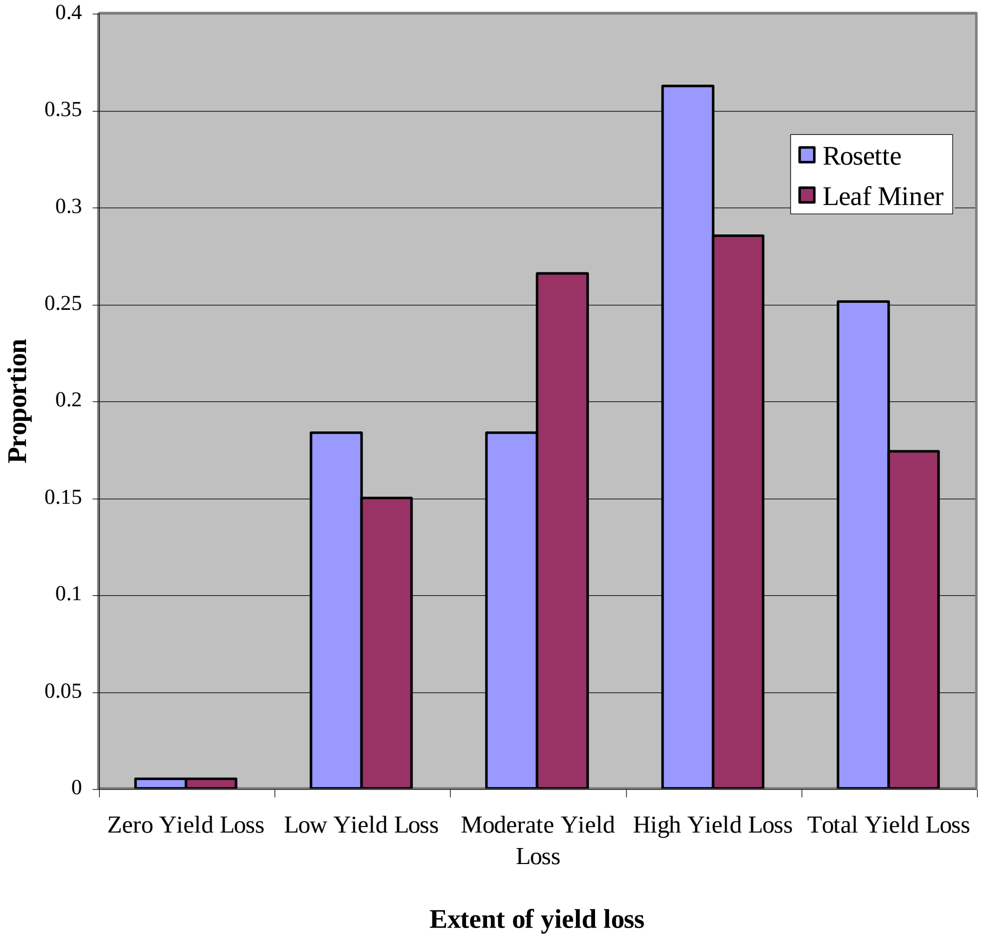
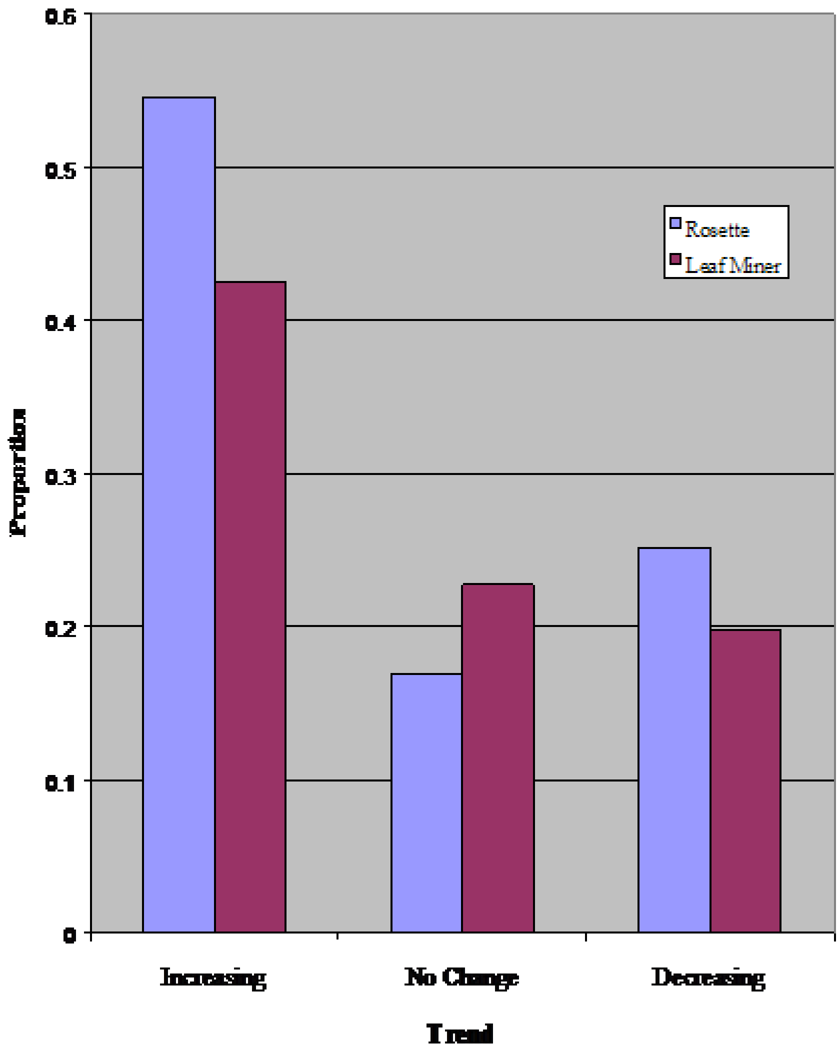


Figure 1 indicates that both of these biotic constraints are clearly perceived to lead to serious yield losses by farmers (especially for rosette disease). Farmers' perceptions of changing trends in the occurrence of these constraints are captured in Figure 2. It indicates that both rosette and leaf miner are regarded as increasing problems in this system, with greater overall concerns with regard to rosette. It is perhaps important to remember at the time of the DFID Teso needs assessment in 1998, leaf miner was not mentioned as a significant constraint in groundnut production, which may indicate that it is still on the increase.

[3] This meaning being able to identify the disease/pest and describe the symptoms

Figure 2 Farmers' perceptions of occurrence trend in rosette disease and leaf miner



Desired characteristics and colour preferences

Most farmers prefer red-seeded nuts (46.8%), with 29.5% expressing no colour preference and 23.7% preferring tan-seeded nuts. When asked to explain the factors behind their colour preferences they mentioned; the market (18.8%), attractiveness (7.2%), taste (3.9%) and oil content (1.0%). Most farmers (nearly 70%) however did not or could not identify the reasons behind their colour preferences. Some of these preferences may also have been confused with general desired varietal characteristics (i.e. not directly related to colour) which are outlined in Table 3.

Table 3 indicates strong preferences for characteristics such as yield, disease (rosette) resistance, early maturation, drought tolerance, marketability and taste – most of which are embedded in the varieties that were tested on-farm during the project. There are of course many other characteristics identified by farmers which are listed in Table 3. It is important to note that farmers clearly express preferences for multiple varietal characteristics with an average of more than four for each farmer.

Table 3 Desired varietal characteristics

Characteristic	Number of farmers	% of all farmers
Yield	170	82
Disease (rosette) resistance	141	68
Marketability	118	57
Early maturing	116	56
Drought resistance	92	44
Taste	92	44
Big-seeded	38	18
Ease of harvest	25	12
Colour preferences	20	10
Easy to pound	18	9
Uniform maturity	18	9
Stores well	5	2
Small seeded	3	1
Pest resistance	3	1
Oil content	3	1
Late maturing	1	0
Total	**869**	**Average of 4.19 desired characteristics per farmer**

Groundnut production and marketing parameters

The use of purchased inputs on groundnuts is not common with the exception of insecticides. These were used by 33.3 per cent of the farmers surveyed, with less than one per cent using other inputs such as fertiliser, herbicides and rodenticides. Traditional (local) varieties were also found to have higher planted areas than newer, improved varieties (in the last main season) 1.32 acres (sd=1.06) compared to 0.76 acres (sd=0.74), though there are clearly big differences between individual farmers. Most farmers only grow groundnut in the main season, though 18.3 per cent were found to have some second season plantings

All the surveyed households used groundnuts for their own home consumption in a number of different ways (sauces/roasting etc.). Most (63.7%) were also found to be selling some of their production; an average of 38 per cent of total production. The majority of these sales (79.6%) were in unshelled form. There was little evidence of further value adding in the system. There were variations between farmers in temporal marketing patterns with around 45 per cent selling in a single, short period (generally very soon after harvest). The rest staggered sales through the year depending on their cash requirements.

Figures 3 and 4 highlight the intra-household (gender) distribution of decision-making in production and marketing spheres respectively. These charts indicate that there is some variation between the intra-household distribution of production and marketing decisions but that most are taken jointly between men and women. Table 4 indicates that women may have less influence in marketing decisions than men, the reverse being true in the production sphere, though the proportion of joint decision making in marketing is significantly higher than in production.

Figure 3 Intra-household production decision making

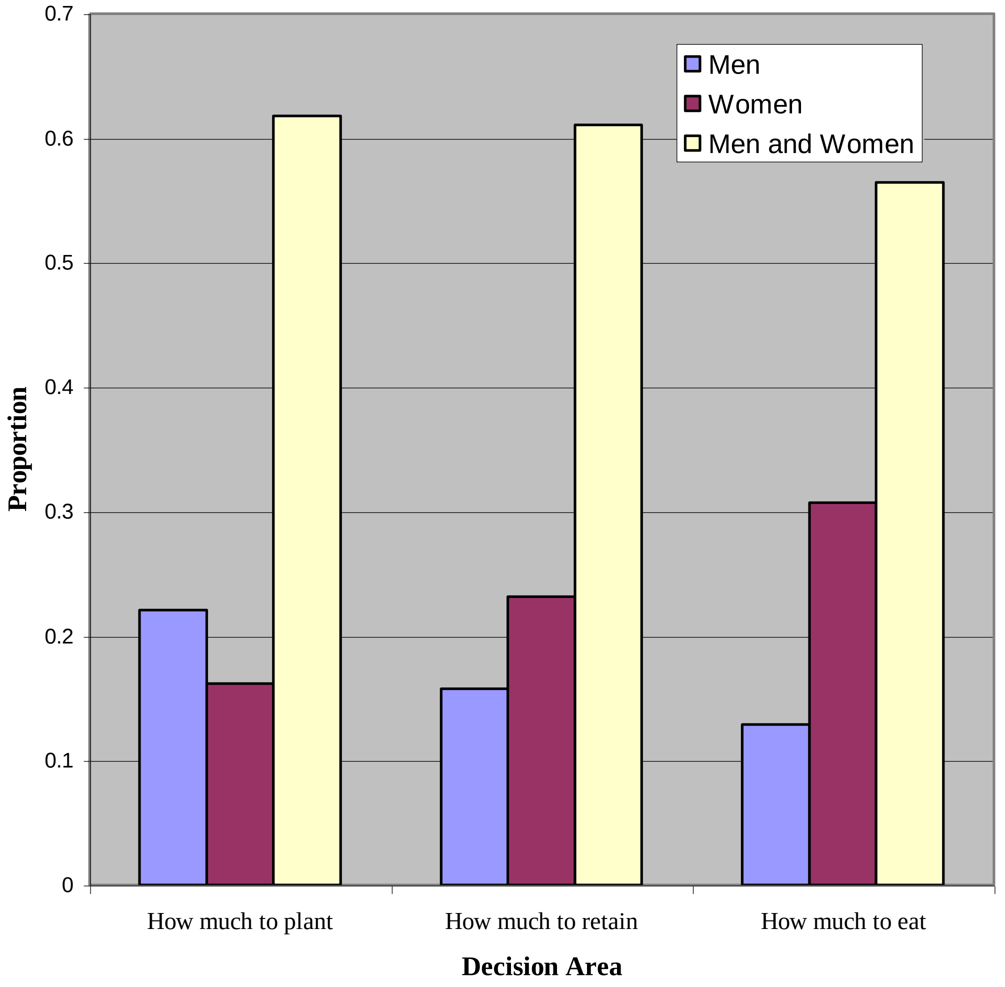
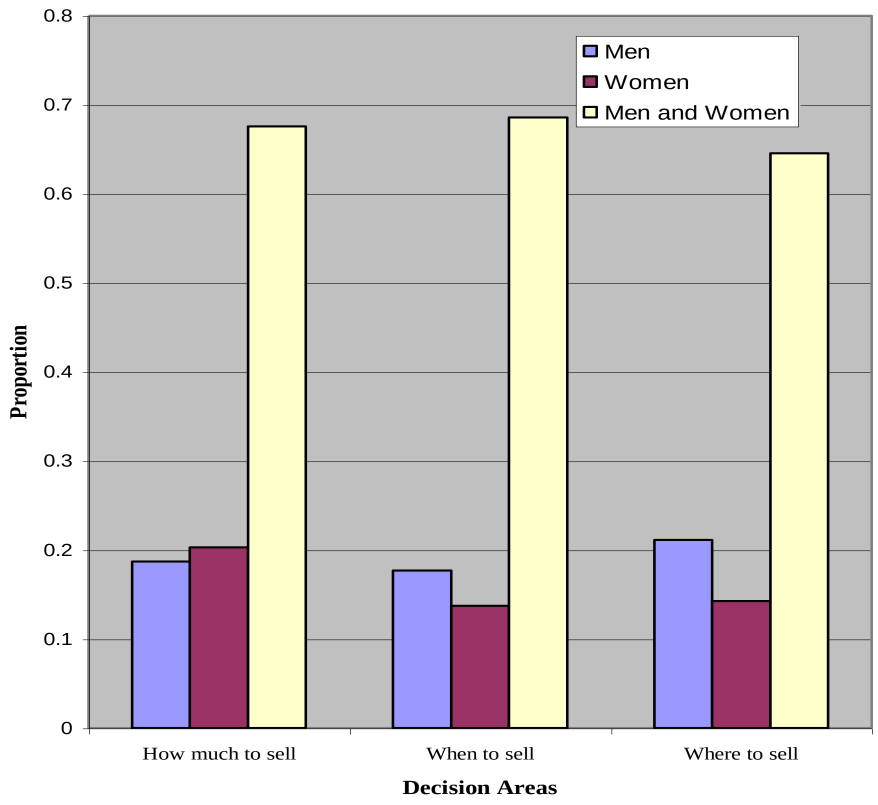


Table 4 Summary of intra-household decision making (proportions reporting)

	All production	All marketing
Men	0.17	0.19
Women	0.23	0.16
Men and women	0.60	0.75

Figure 4 Intra-household marketing decisions



Agricultural knowledge information system

Table 5 indicates a wide range of information sources that are influencing the agricultural practices of farm households in the survey area. The most important ones were: neighbours (and friends), radio, extension services and parents. On average, households had 3.3 sources of agricultural information.

Table 5 Sources of agricultural information

Information source	Number of farmers	% of all farmers
Neighbours/friends	154	74
Radio	135	65
Extension	99	48
Parents	72	35
Newspaper	67	32
School	48	23
NGOs	36	17
Training workshop	33	16
On-farm research and demonstration	33	16
Other	7	3
Total	**684**	**Average of 3.3 sources per farmer**

There is a very low incidence of group membership in this area; less than 20 per cent of farm households indicated they were members of any type of group. All group membership is accounted for by extension contact groups or loose farmer associations.

Review of household variables

According to the survey results the average age of household heads is 42 (with an sd of 15), who have been farming[4] for an average of 22 years (sd=14). The proportion of households that were found to be female headed is 15 per cent across the 3 districts; though this proportion was twice as high in Katakwi compared to both Soroti and Kumi. The reasons behind these patterns are not clear; the two most common cited reasons were death of husband and divorce; however nearly ¾ of female-headed households did not provide an answer to the question.

Table 6 provides details on education levels and indicates that the majority of the surveyed households had low levels of formal education[5]; nearly 60 per cent were illiterate or had basic primary schooling only.

Table 6 Formal education levels (highest attainment in household)

Education level	Number of households	% of all households
Illiterate	34	16
Primary schooling	93	43
Secondary-S4/Junior School J3	64	31
High School – S6/ Technical School – TTC	8	4
Greater than S6 – University and higher TTC	7	3

A significant proportion (16.4%) of the respondents identified themselves as part-time farmers only, with primary interest in other economic activities. Of this group most were dedicating half or more of their time to other economic activities. However a much larger proportion of households (33%) identified themselves as being involved in non-farm economic activities and these are outlined in Table 7.

Table 7 Sources of non-farm income

Income source	Number of Households	% of all households
Formal Employment	29	14
Trading/Small Business	17	8
Remittances	9	4
Casual Labouring	7	3
Basket Making/Winnowing	1	0
Total	**63**	**Average of 0.3 across all households**

[4] Meaning being in control and making enterprise level decisions
[5] Figures relate to the highest level of attainment in the household

General system information

Dependent variables that can act as wealth proxies (such as land size and cultivated areas) were found to be closely associated with education levels[6] and household maturity[7]. These variables were also found to be important in explaining participation in non-farm economic activities. However age and education were not found to be a significant in explaining the presence of part-time farming activity in households. The latter was found to be related only to the presence (or absence) of formal employment and small business activity.

Presence of formal employment[8] was found to be a function of education levels. This was not the case for small business/trading activity for which no significant relationships could be established with other factors or variables[9]. The total number of income sources[10] was found to be related to education and household maturity along with gender of household head[11] and one particular district[12].

Differences between total and cultivated farm areas[13] were found to be related to other system wide constraints. These included labour shortages, soil fertility issues and concerns over output (market) prices.

Groundnuts/market integration

A significant proportion of households (18.4%) were found to be growing groundnuts over two seasons[14] and there were no useful statistical explanations of the presence of this activity on a household basis. However the extent of the uptake of new groundnut varieties[15] were related to education levels and certain information sources[16].

Colour preferences were found to be related to extent of market integration[17]. A preference for red-seeded groundnuts was positively related to market integration, the converse being true for tan coloured seed. Where farmers had no colour preference this was also found to be negatively associated with levels of market integration.

Other information/promotion issues

The total number of agricultural information sources available to farmers was related to some wealth indicators (e.g. cultivated farm area) but not to education. The determinants of access to individual agricultural information sources were also assessed, and are listed in Table 8

Table 8 Determinant of access to selected agricultural information sources

Information Source	Access Determinant
Government Extension	Age of household head
NGO	Education level, cultivated area
Radio	Age of household head, education level, male household head, cultivated area
School	Education level
Newspaper	Education Level, cultivated area

[6] Defined as general education level and not number of years
[7] Using age of household head as a proxy variable
[8] Tested as a dummy variable.
[9] But indicating that formal education is necessarily a pre-requisite to enter this enterprise area.
[10] A measure of livelihood diversification.
[11] Positively related to male headship.
[12] In this case Soroti; all districts were entered into the model as dummy variables
[13] A proxy for land opening constraints.
[14] Despite problems with the long duration of the newer rosette disease resistant lines.
[15] Measured by their planted area rather than their presence or absence.
[16] The only two significant sources were found to be contact with extension services and visiting researchers.
[17] Proxied by proportion of groundnut production sold by the household

This is not a fully inclusive list but indicates how much variation there potentially is between different promotional approaches and information channels. Different channels may well reach very different groups of people and exert different levels of influence on agricultural practices[18].

Conclusion

The survey has allowed the analyses of some of the broad parameters that influence the structure of household livelihoods in this geographic area, and the importance of groundnut production and marketing in these. What would appear to be critical is influencing the factors that affect the uptake of new technology in general and improved groundnut varieties in particular. The analysis in the last section would indicate that these fall into two different areas: education and access to information (and, in turn, the factors and variables that influence access to different information channels). It is in the latter area that this project was directly involved in to ensure that adoption of new rosette resistant lines is optimised.

The database developed from the survey has been distributed to collaborators and interested parties such at CORSU, SAARI, AT (Uganda) and DFID (EA). A copy of the database is attached in the CD provided.

Appendices on analytical statistics

Detailed results are presented in the following statistical appendices:

2. Determinants of total and cultivated area
3. Determinants of participation in non-farm activities
4. Determinants of participation in formal employment and trading/small business activity
5. Determinants of total income sources
6. Determinants of differences between total and cultivated area
7. Determinants of uptake of new varieties – educational influences
8. Determinants of uptake of new varieties – information sources
9. Determinants of uptake of new varieties – combined education and information sources
10. Determinant of number of information sources
11. Market integration and colour preferences
12. Determinants of access to extension advice
13. Determinants of access to NGO (agricultural) advice
14. Determinants of access to radio transmitted agricultural advice
15. Determinants of access to newspaper based agricultural advice

[18] These relationships need to be statistically investigated in much more depth e.g. looking at whether individual information sources influence the uptake of new varieties and this will be considered in further papers and publications.

1.2 . Stakeholder workshops involving farmers, scientists, NGOs and extension workers (year 1 and 3).

Two workshops were held during the course of the project. These were written up as proceedings soon after each workshop and distributed to interested parties. In addition meetings were held at least twice a year throughout the project with the collaborators (SAARI, AT Uganda, SOCADIDO, DAOs of the Teso Districts and IDEA) to discuss the progress of the project, on-farm and on-station trial designs and implementation, bulking up and distribution of seed for both small-holder farmers and commercially. On-farm visits were carried out by SAARI, AT (Uganda), DAOs, SOCADIDO and project personnel from NRI and ICRISAT on a regular basis to advise, train and collaborate in trials.

First workshop held 24-25th February 2000

Over the two-day workshop, presentations were given on the development of new rosette resistant varieties by ICRISAT-Malawi, and the performance and release of these lines in Uganda by SAARI scientists. Economic considerations for the farmer were presented by staff from two local NGOs (AT Uganda and SOCADIDO), NRI and NARO Entebbe while issues associated with seed production and multiplication were discussed by a representative from the Ugandan Seed Project. Finally an NRI biometrician provided an introduction to biometric inputs into on-farm trials. As well as developing linkages and providing information to key players their views were discussed on groundnut production**,** the impact of rosette disease and the potential role of early maturing, disease resistant varieties in the Teso system. Feedback was given on how the project can be improved in order to develop truly participatory approaches, which would promote uptake and adoption of resistant lines. An electronic copy of the workshop proceedings is provided on the CD with this report and the programme for the workshop is shown in Appendix 16 and a list of the participants in Appendix 17.

Second workshop held 13th March 2002-05-20

The workshop was held at Kumi in Uganda and was opened by the acting Director of SAARI, Dr Serunjogi. Participants included representatives from NARO, DFID, AT-Uganda, SOCADIDO, IDEA, Department of Agriculture Offices in Kumi and Katakwi and the FAO-supported Farmer Field School programme as well as the international collaborators

The main issues covered during the workshop were:

- *Varietal development and evaluation*: Data were presented from on-station and on-farm trials that would be used to support the submission of two resistant lines for approval by the National Variety Release Committee. Subsequently, on 3rd April this Committee officially released ICGV-SM 93530 and ICG 12991 as Serenut 3R and Serenut 4T, respectively. The results of on-farm trials were summarised where the test lines produced comparable yields to the susceptible farmer choice varieties in a year when rosette disease was very low. Consequently, the value of the resistant material would be expressed very clearly when disease pressure was high, as had occurred in previous seasons. In farmer evaluations, Serenut 2 and IGC-12991 consistently received the highest scores, with IGC-12991 commonly referred to by farmers as 'New Erudurudu'. The results of the baseline survey were summarised and related the progress made with the varietal development and evaluation to some of the key factors identified in the survey; for example, in the range of characteristics that farmers looked for in a new variety. The database arising from the survey is a resource available to project collaborators.
- *Virus identification*: Dr Naidu outlined the major seed-borne diseases of groundnut that posed a potential threat to future production. It was agreed that closer links between

researchers and the Plant Protection Department in the Ministry of Agriculture were needed, but that both trained staff and laboratory facilities were limiting.

- *Marketing constraints*: concerns were raised by Dr Muhuku of IDEA about seed quality; specifically, seed viability, small and uneven seed size and absence of characteristics suitable for processing. The quality of the new varieties was considered to meet the requirements of small-scale farmers who were the main beneficiaries of the project, and thus fulfil the mandate of the CPP, and ICG-12991 does appear to be suitable for some confectionery uses. Nevertheless, the point was taken that quality issues were becoming increasingly important to enable farmers to add value to their produce and thus enhance their income earning opportunities. In this connection, it was noted that another short-duration Spanish type (ICG-2) produced more uniform seed than ICG-12991 in trials in Malawi and that this should be included in future on-farm evaluations.
- *Participatory approaches to germplasm evaluation and dissemination*: reports from AT-Uganda, SOCADIDO and the DAO's revealed that there are several approaches that may be taken in working with farmer groups. Also, working with certain categories of groups is more productive than with others. Dr Laker-Ojok of AT-Uganda described a new 'promotional' research project funded by DFID through the CPP, and led by AT-Uganda, which involves the farmer-to-farmer transfer of rosette-resistant seed. This work arises directly from the current project and demonstrates the success of the project in establishing a network of partners working effectively together to contribute to the development of a groundnut seed distribution system in the Teso system.
- *Knowledge gaps and knowledge transfer*: examples were provided by James Okoth and from the experience of AT-Uganda where farmers lacked the necessary information to optimise their groundnut production systems. The Farmer Field Schools were actively seeking to address this situation. The completion of a groundnut production manual for Uganda, copies of which were distributed at the workshop, is also expected to make a major contribution to closing knowledge gaps. The manual was well received by participants and additional copies were requested.
- *Future research needs*: leaf miner was identified as a potentially serious production constraint. Dr Epiru (SAARI) presented preliminary data from field sampling conducted under the new CORSU-funded project, which showed large populations of leaf miners at some locations, with greatest abundance in the second season. The need to continue the rosette resistance breeding effort was recognised. In this connection, Dr Busolo-Bulafu (SAARI) referred to the cross between Serenut 1 and Serenut 2 that had been made at SAARI.

An electronic copy of the workshop proceedings is provided on the CD with this report and the programme for the workshop is shown in Appendix 18 and a list of the participants in Appendix 19.

2.1 On-station screening trials for rosette disease and vector resistance established and economic gain measured

Introduction

Varietal resistance to groundnut rosette disease is the most practical and effective way to manage the disease and to reduce yield loss. Collaboration between the Oilseeds programme at NARO and ICRISAT plant breeders was fostered under the previous project (R6811) utilising sources of resistance identified and developed at ICRISAT Lilongwe. The overall objective was to incorporate rosette resistance and several other key traits in order to meet the requirements of farmers in the TESO system. The most important traits were identified as being high yield potential, short duration and drought resistance as well as quality characteristics that would meet the requirements of consumers in the market place.

As a result of these efforts under R6811, two rosette resistant varieties were released in 1999; Igola-1 and Serenut-2. Serenut-2, in particular, has been widely adopted by farmers. However, one limitation is that, as with Igola 1, Serenut-2 is a medium duration variety and hence it is vulnerable to end-of-season droughts. Short duration genotypes with resistance to rosette have been developed by ICRISAT and a major aim of this project was to evaluate these in the TESO districts to determine their suitability for release in Uganda.

Since 1999, breeding materials with resistance to groundnut rosette, early leaf spot or with wide adaptation were provided by ICRISAT breeders for evaluation at SAARI and are shown in Table 9.

Table 9 Varieties provided by ICRISAT for evaluation at SAARI

Variety		**Resistance**	**Date**	
ICGV-SM	93524	Rosette	May	1999
ICGV-SM	93530	Rosette	May	1999
ICGV-SM	93535	Rosette	May	1999
ICGV-SM	94581	Rosette	May	1999
ICGV-SM	99540	Rosette	May	1999
ICGV-SM	94588	Rosette	June	1999
ICG	12991	Rosette	May	1999
ICGV-SM	90704	Rosette	March	2000
CG7		Wide adaptation	March	2000
ICG 12991		Rosette	March	2000
ICGV-SM	93524	Rosette	March	2000
ICGV-SM	93530	Rosette	March	2000
ICGV-SM	93535	Rosette	March	2000
ICGV-SM	94581	Rosette	March	2000
ICGV-SM	99540	Rosette	March	2000
ICGV-SM	94584	Rosette	March	2000
ICGV-SM	99529	Rosette	March	2000
ICGV-SM	99563	Rosette	March	2000
ICGV-SM	99569	Rosette	March	2000
ICGV-SM	93528	Rosette	March	2000
JL 24		Wide adaptation	Sept.	2000
ICGV-SM	99540	Rosette	Sept.	2000
ICGV-SM	99556	Rosette	Sept.	2000
ICGV-SM	99553	Rosette	Sept.	2000
ICGV-SM	99532	Rosette	Sept.	2000
ICGV-SM	99562	Rosette	Sept.	2000
IGG 12991		Rosette	Sept.	2000
ICG 12998		Rosette	Sept.	2000
ICGV-SM	99527	Rosette	January	2001
ICGV-SM	99528	Rosette	January	2001
ICGV-SM	99529	Rosette	January	2001
ICGV-SM	99540	Rosette	January	2001
ICGV-SM	99543	Rosette	January	2001
ICGV-SM	99568	Rosette	January	2001
ICGV-SM	99569	Rosette	January	2001
ICGV-SM	99574	Rosette	January	2001
ICGV-SM	95713	ELS	January	2001
ICGV-SM	95740	ELS	January	2001
ICGV-SM	95741	ELS	January	2001

Materials and Methods

Breeding lines from ICRISAT were bulked up in field plots at SAARI and the most promising lines selected for further evaluation. In 1999, 8 short-duration lines were evaluated for rosette resistance, adaptability, yield and other attributes at SAARI and 5 other locations. The test lines were ICG 12991 (vector resistant), ICGV-SM 93530, 93535, 93524, 94581, 99540, 94584 and 93557. Groundnut rosette - susceptible (Red Beauty) and resistant (Igola 1 or Serenut 2) controls were included in the field trials. The ten lines were tested in a completely randomised block design, with four replications. Each plot consisted of six rows, 5 metres in length with a plant spacing of 45 x 10 cm.

As the amount of disease inoculum at SAARI was found to be sufficiently high, the original plan to use infector rows to increase disease pressure was not followed. Plants were scored for rosette disease and leafspot symptoms at harvest. The dry weight of groundnut pods was recorded following a standard protocol used at ICRISAT-Malawi.

Further crosses were made at ICRISAT-Malawi using carefully selected parents and conventional breeding techniques. The objective was to create hybrids with a range of resistance combinations that could be used for further crop improvement. This included combinations of virus and vector resistance that were designed to provide more durable resistance to rosette disease.

Results

The short duration lines matured in 98 to 111 days and so would allow two crops a year to be planted (Table 10). Most of the lines, both short and medium duration, showed good resistance to rosette in trials in 1999 (Appendix 20, Table 1) and 2000 (Table 10 and Appendix 20, Table 2). In the 2000 first rains trial at SAARI, the mean incidence of rosette disease in the susceptible short duration control Red Beauty was 30%. By contrast, mean rosette incidence in each of the test lines was less than 1% indicating a strong level of resistance. Leafspot incidence was relatively high in some lines, although the highest leafspot levels were recorded in Red Beauty. However, most of the infection was with early rather than late leafspot and this would not be expected to have a serious effect on yield. The yield off each test line was significantly greater than Red Beauty and four lines yielded better than Igola 2.

Results for rosette incidence and yield from the 2001 first rains trials at five locations are shown in Table 11. At most locations, rosette incidence was low even on the susceptible check Red Beauty. However, at Kuju (27%) and Ngetta (20%) rosette incidence on Red Beauty resulted in significant yield losses. Under these conditions the value of the resistant test lines was clearly demonstrated. Even under conditions of low rosette disease incidence at other sites, the yield of some breeding lines was significantly greater than that of Red Beauty and comparable to that of Serenut 2. The test lines continued to perform well in the 2001 second rains trials that were conducted at four locations (Appendix 20, Table 3).

Table 10 Evaluation of selected varieties and breeding lines for yield of dry pods and resistance to rosette disease and leafspot in on-station trials at SAARI in 2000 (first rains). Data are presented with standard errors.

Variety/Line	*Days to harvest*	*Leafspot score (1-9)*	*Rosette incidence (%)*	*Yield: weight of dry pods (kg)*
Short duration				
12991	98.3 ± 0.3	5.8 ± 0.3	0.5 ± 0.3	2.6 ± 0.1
93524	108.3 ± 0.3	4.8 ± 0.9	0	2.4 ± 0.1
93530	108.5 ± 0.3	3.5 ± 0.3	0	2.3 ± 0.5
93535	109.3 ± 0.3	3.8 ± 0.3	0	1.7 ± 0.2
93557	106.8 ± 0.3	3.0 ± 0.7	0.3 ± 0.3	1.7 ± 0.1
94581	110.5 ± 2.2	4.3 ± 0.6	0	2.9 ± 0.2
94584	110.8 ± 2.1	4.0 ± 0.4	0.3 ± 0.3	2.3 ± 0.3
99540	98.5 ± 0.3	5.5 ± 0.5	0.3 ± 0.3	3.4 ± 0.3
Igola 2	111.3 ± 1.9	3.8 ± 0.5	0	2.1 ± 0.1
Red Beauty	98.0 ± 0	6.8 ± 0.3	29.5 ± 8.8	1.1 ± 0.1
Medium duration				
86708	122.5 ± 0.7	6.0 ± 0	6.5 ± 1.2	1.9 ± 0.4
88711	122.5 ± 0.7	5.8 ± 0.3	18.0 ± 10.0	1.8 ± 0.3
88737	123.8 ± 0.3	3.3 ± 0.3	0	1.9 ± 0.4
89751	123.0 ± 0.4	5.3 ± 0.3	0	2.8 ± 0.2
89786	123.0 ± 0	4.8 ± 0.5	0	2.3 ± 0.3
89790	122.8 ± 0.5	4.3 ± 0.5	0	2.9 ± 0.4
91701	123.5 ± 0.3	4.0 ± 0	0.3 ± 0.3	2.5 ± 0.2
91707	123.3 ± 0.3	4.0 ± 0.6	0	2.6 ± 0.3
93533	120.5 ± 0.5	6.0 ± 0	0	2.5 ± 0.03
Serenut 1	121.5 ± 0.5	5.8 ± 0.3	50.5 ± 11.2	1.3 ± 0.3

Based on the results of these trials and on-farm trials conducted with other project collaborators (see section 2.2) two lines were submitted to the Uganda Seedboard for varietal release. Consequently, in March 2002 ICG 12291 and ICGV-SM 93530 were officially released under the names of Serenut 3R (93530, R = red-seeded) and Serenut 4T (12991, T = tan-seeded), respectively. The release of a red-seeded and a tan-seeded variety provides farmers with a choice that will help them to respond to the requirements of different markets. In addition, although the seed size is not optimal, ICG 12991 is suitable for some confectionery purposes so that there is the potential for farmers to add value to their product. A sister line to ICG 12991 has been evaluated at ICRISAT-Malawi and this has a larger and more uniform seed size. This line will be evaluated in Uganda in subsequent seasons.

Table 11 Evaluation of selected varieties and breeding lines for yield of dry pods and resistance to rosette disease in on-station trials at five locations in 2001 (first rains). Data are presented with standard errors.

Variety	SAARI		Kumi		Kuju		Nakabango		Ngetta	
	Yield (kg)	*% rosette*	*Yield (kg)*	*% rosette*	*Yield (kg)*	*% rosette*	*Yield (kg)*	*% rosette*	*Yield (kg)*	*% rosette*
93530	3.25 ± 0.48	0	2.13 ± 0.13	0	1.40 ± 0.12	0	1.88 ± 0.18	0	1.38 ± 0.13	0
93535	2.55 ± 0.49	1.25 ± 0.75	1.63± 0.13	0.58 ± 0.48	1.15 ± 0.10	1.25±0.75	1.40 ± 0.09	0	1.50 ± 0	0
93524	2.50 ± 0.20	0	1.88 ± 0.24	0	1.05 ± 0.09	0.5±0.5	1.35 ± 0.03	0	1.25 ± 0.14	0
94581	1.75 ± 0.43	0	1.63 ± 0.13	0	1.13 ± 0.13	0	1.73 ± 0.05	0	1.13 ± 0.13	0.75 ± 0.25
99540	3.40± 0.56	0.25± 0.25	3.00 ± 0.29	0.08 ± 0.08	2.10 ± 0.17	1.00±0.41	1.85 ± 0.16	1.35 ± 0.30	1.50 ± 0	2.00 ± 0.58
12991	3.00± 0.35	0	2.25 ± 0.32	0.08 ± 0.08	1.73 ±0.08	0	1.48 ± 0.14	0.18 ± 0.18	1.13 ± 0.13	4.00± 2.74
Red Beauty	1.75 ± 0.14	2.78 ± 1.38	1.75 ± 0.48	0.35 ± 0.20	0.65 ± 0.12	27.0± 12.61	1.18 ± 0.19	3.90 ± 2.27	0.85 ± 0.15	20.25±10.9
94584	2.10 ± 0.30	0.25 ± 0.25	1.13 ± 0.13	0	1.00 ± 0.10	0	1.78 ± 0.17	0	1.20 ± 0.20	0
93557	2.00 ± 0.20	0.18 ± 0.18	2.88 ± 0.13	0	1.45 ± 0.10	0.25 ± 0.25	1.65 ± 0.13	0	1.38 ± 0.13	1.25 ± 0.48
Serenut 2	2.78± 0.24	0	2.75 ± 0.14	0	1.58 ± 0.16	0.50 ± 0.50	2.35 ± 0.28	0	1.38 ± 0.13	0

More than twenty hybrid groundnut lines were developed from crosses made at ICRISAT-Malawi in the 2000-01 cropping season. These breeding lines will be utilised in further groundnut improvement work at Malawi and will be made available to the Oilseeds programme at SAARI to help ensure that groundnut production in Uganda continues on a sustainable basis.

Table 12 Hybrid groundnut lines developed from crosses made at Lilongwe during the 2000/2001 cropping season.

CROSS NUMBER	FEMALE PARENT	MALE PARENT	REASON FOR CROSS	DATE
ICGX-SM 20001	ICGX-SM 99005	ICG 12991	Back cross to Aphid res[1].	2000
ICGX-SM 20002	ICGX-SM 99005	Akwa	Back cross Aphid susc[2].	2000
ICGX-SM 20003	ICGX-SM 99022	ICG 12991	Back cross to Aphid res.	2000
ICGX-SM 20004	ICGX-SM 99022	ICGV-SM 95741	Back cross to ELS res. and aphid susc.	2000
ICGX-SM 20005	JL 24	RMP 12	Rosette res. markers- Morag	2000
ICGX-SM 20006	ICGV-SM 90704	Chalimbana(ICG5262)	Rosette GRV x Bold seeded	2000/2001
ICGX-SM 20007	RMP 12	Chalimbana(ICG5262)	Rosette GRV x Bold seeded	2000/2001
ICGX-SM 20008	ICG 12991	Chalimbana(ICG5262)	Aphid res. X Bold seeded	2000/2001
ICGX-SM 20009	ICG 12991	ICGV-SM 95713	Aphid res x ELS[3] res.	2000/2001
ICGX-SM 20010	ICG 12991	ICGV-SM 95714	Aphid res x ELS res.	2000/2001
ICGX-SM 20011	ICG 12991	ICGV-SM 95740	Aphid res x ELS res.	2000/2001
ICGX-SM 20012	ICG 12991	ICGV-SM 95741	Aphid res x ELS res.	2000/2001
ICGX-SM 20013	ICGV-SM 90704	ICGV-SM 95713	Rosette virus x ELS res.	2000/2001
ICGX-SM 20014	ICGV-SM 90704	ICGV-SM 95714	Rosette virus res. x ELS res.	2000/2001
ICGX-SM 20015	ICGV-SM 90704	ICGV-SM 95740	Rosette virus res. x ELS res.	2000/2001
ICGX-SM 20016	ICGV-SM 90704	ICGV-SM 95741	Rosette virus res. x ELS Res.	2000/2001
ICGX-SM 20017	ICG 12991	ICGV-SM 99529	Aphid res. x rosette virus res.	2000/2001
ICGX-SM 20018	ICG 12991	ICGV-SM 99543	Aphid res. x rosette virus res.	2000/2001
ICGX-SM 20019	ICG 12991	ICGV-SM 99568	Aphid res. x rosette virus res.	2000/2001
ICGX-SM 20020	ICG 12991	ICGV-SM 99574	Aphid res. x rosette virus res.	2000/2001
ICGX-SM 20025	ICGV-SM 90704	ICGV-SM 99804	Rosette virus res. x Conf.[4]	2000/2001
ICGX-SM 20026	ICGV-SM 90704	ICGV-SM 98702	Rosette virus res. x Conf.	2000/2001
ICGX-SM 20027	ICGV-SM 90704	P52 - 4	Rosette virus res. x Conf.	2000/2001

[1] res. = resistant. [2] susc. = susceptible. [3] ELS = early leaf spot. [4] Conf. = confectionery

2.2. On-farm trials with and assessment by farmers and other stakeholders of varietal performance.

Organisation and structure of trials

The trials were conducted across the 3 main districts of the Teso farming system (Soroti, Katakwi and Kumi) involving 3 clusters of 8 farmers in each district; a total of 24 farmers in each district and 72 farmers overall. For the purposes of data analysis, each farmer was treated as a block and had 7 varieties in each trial; these consisted of 4 new resistant lines, Serenut 2, Erudurudu (control), and the farmer's own choice (Table 14). The trials were organised through the DAO's office in each District, and by SOCADIDO and AT (Uganda). Seed was provided from SAARI for the first 6 varieties (in bags numbered 1-6), with farmers providing seed of their own choice (variety 7). The rows of varieties were planted in a random order using computer-generated random numbers. The varieties used by farmers as their own choice is shown in Table 15. Trials were designed and analysed in consultation with farmers, biometricians and research partners and appropriate statistical methods were utilised to analyse the results. Due to a number of factors, data from some farmers had to be discounted (or was not collected), producing a final data set based on 57 farmers. The trial design is described in more detail in Appendix 21 and additional information and statistics are shown in Appendices 22-32.

Table 13 Varieties used in the trials

VARIETY		RESISTANCE
1	12991	Vector resistant
2	93530	Virus resistant
3	93535	Virus resistant
4	94581	Virus resistant
5	Erudurudu	Susceptible control
6	Serenut 2	Virus resistant control
7	Farmer's own	Susceptible or virus resistant

Table 14 Proportion of varieties used by farmers as their own choice

Variety	%	Variety	%
Ebaya	10.5	Igola 1 (resistant)	43.9
Egoromoit	7.0	Obino	8.8
Ematuda	1.8	Obokorit	1.8
Erudurudu	15.8	Okuruk	1.8
Erotot	1.8	White valencia	1.8
Etiirait	5.3		

Trial farmers and the broader farming population

The trial farmers were selected by collaborating partners and were generally groups of farmers they have worked with in the past. Results from the survey work also conducted under this project (see section 1.1) indicate that contact with certain knowledge sources is positively related to some wealth indicators; it is therefore useful to compare the trial farmers against the general Teso farming population. The only factor on which data was collected from both the survey and trials was cultivated area which is a very useful proxy wealth variable. Although exact measurements of trial farmers were not collected the trial data indicate that most farmers (32/57) cultivated between 3 and 8 acres in the main growing season. This compares with an average of 4.81 cultivated acres from the survey of 208 households, perhaps indicating slightly greater cultivated areas among trial farmers.

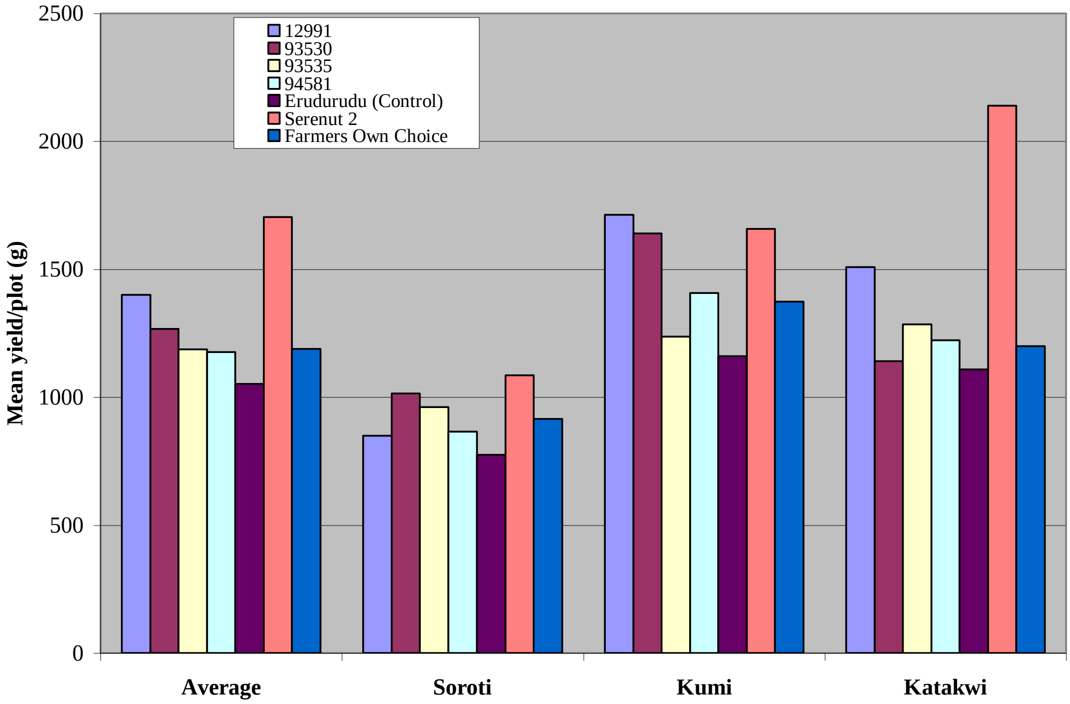
Other result influencing factors

In the main 2001 growing season GRD incidence was very low, so that the relative performance of the new resistant lines was understated both in terms of yield differentials and farmers perceptions. It is necessary to bear this in mind when interpreting the results in the next three sections; greater rosette incidence (as is the case in most seasons) would have led to higher overall performance among the four new lines.

Yield performance

It is clear from Figures 5 and 6 that the new resistant varieties (12991, 93530, 93535 and 94581) performed well compared to the local control (Erudurudu) and farmers own choices, even in this season when rosette disease incidence was low. This appears consistent across all three districts and in terms of both shelled[19] and unshelled yields. Two varieties performed particularly well – Serenut 2 and 12991. There was little difference in the performance of the remaining varieties, which included both new resistant material and traditional local varieties. There was some variation between districts, with overall lower yields in Soroti.

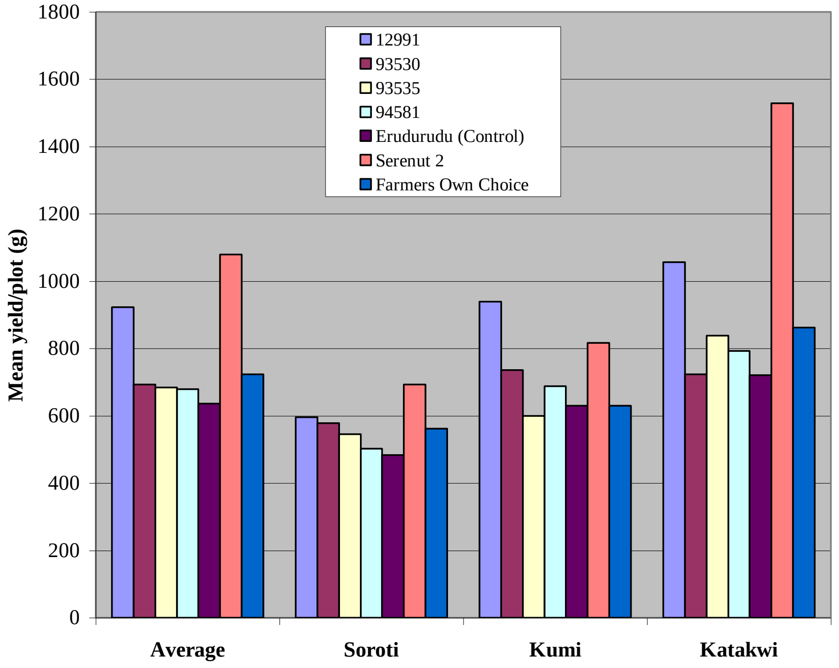
Figure 5 Mean yield per plot : unshelled (g)



Overall the best performing variety was Serenut 2 which is rosette resistant and is already released and is currently being bulked and promoted nationally. However it is a long duration variety and the other four new lines offer both disease resistance and a shorter growing period bringing a wider range of potential benefits to farmers. Of these 4 lines, 12991 yielded well and at significantly higher levels[20] than local varieties. It is difficult to show, on the basis of these data, that the other new lines have any yield benefits to offer over local varieties but it does show that they performed as well as the local varieties where rosette incidence is low.

[19] Shelled weights were not all farmers (in 30/57 cases) and shelling ratios were used in this case. Appendix 26 contains details of the statistical calculations relating to these ratios.
[20] See appendices 24 and 25 for more detailed statistics on yield performance.

Figure 6 Mean yield per plot: shelled (g)



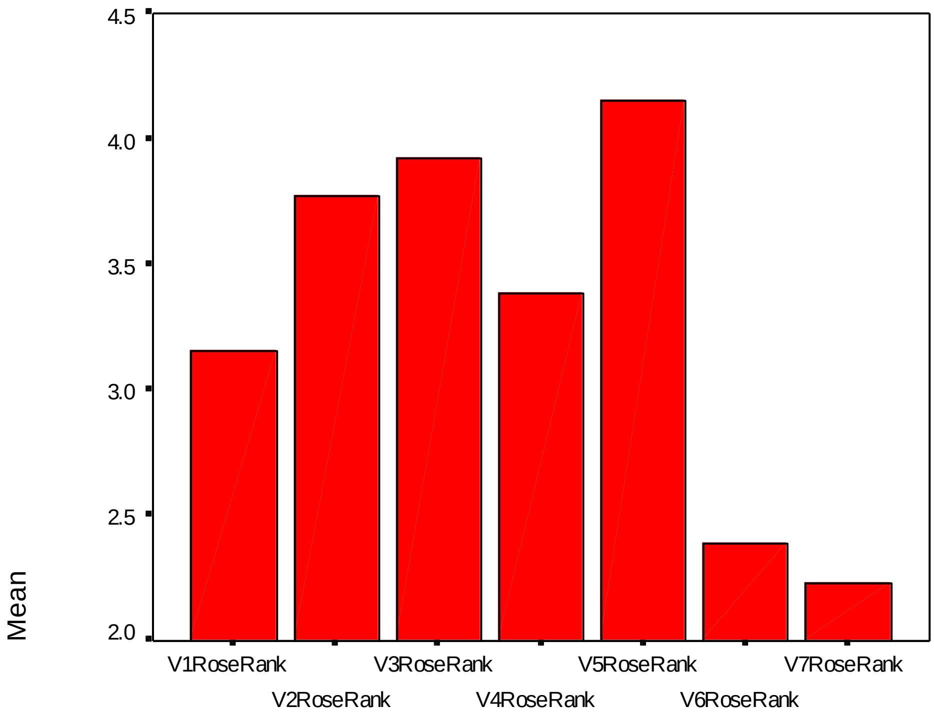
Rosette and leaf spot performance

Each variety was ranked (between 1 and 7, with 7 the greatest) for rosette disease by the trial organisers) and Figure 7 summarises these results. It indicates that there was little to choose between most varieties with most scores between 3 and 4; only Serenut 2 (V6) and farmers own choice (V7) fell outside this range with slightly lower average scores falling between 2 and 2.5. It is very difficult to draw any conclusions from these results, and this can be explained by the very low incidence of rosette disease in this season, and perhaps the different interpretation of the scoring system by different organisers[21]. It is also important to note that many scores were missing (entered as zero in 28 out of 57 cases) because of zero presence of rosette in the trials.

The rankings with regard to leaf spot (Figure 8) are a little different from those of rosette disease with larger differences between average ranks. In particular 12991 (V1) ranked highly, but this is known to be late season leaf spot which has little, if any, yield implications. Other varieties appearing to experience higher leaf spot incidence included Erudurudu (V5) and 93530 (V2); there was very little difference between the remaining 4 varieties. Again however there were many missing observations (or where blanks and zeros were entered in 28/57 cases) and it is therefore difficult to draw any meaningful conclusions.

[21] Particularly the use of blanks, and zeros, in the scoring to indicate the absence of rosette disease – instead of equal 1's. Zero scores were discounted in the graphs and many scores were missing (28/57). See appendix 27 for more details on the statistics relating to these scores and those relating to leaf spot.

Figure 7 Mean rosette disease rankings by variety



Where V1 = 12991, V2 = 93530, V3 = 93535, V4 = 94581, V5 = Erudurudu (control), V6 = Serenut 2, V7 = Farmers own choice.

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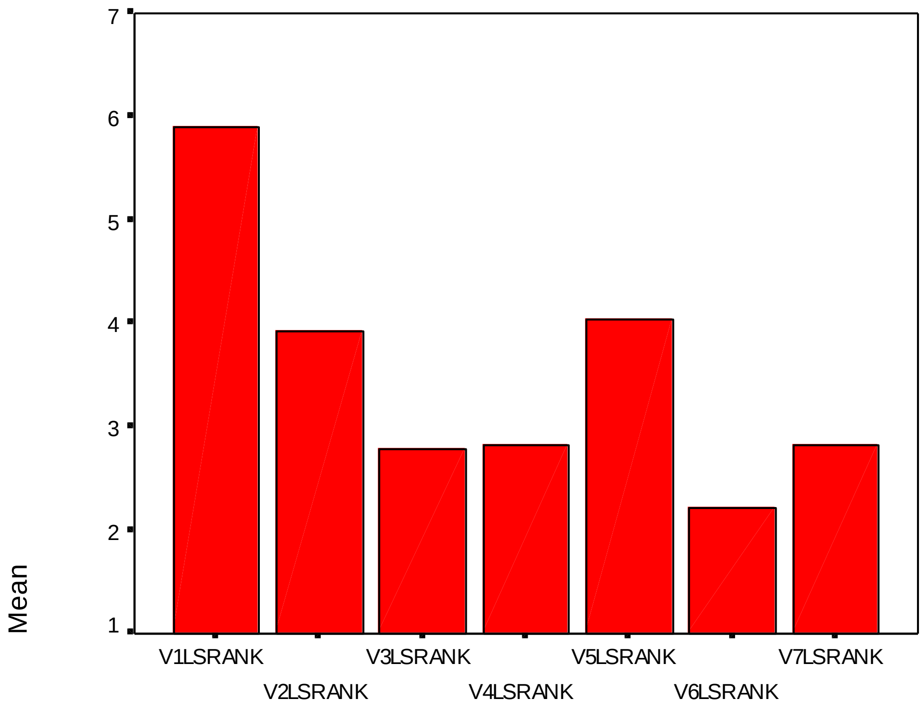
Figure 8 Mean leaf spot rankings by variety

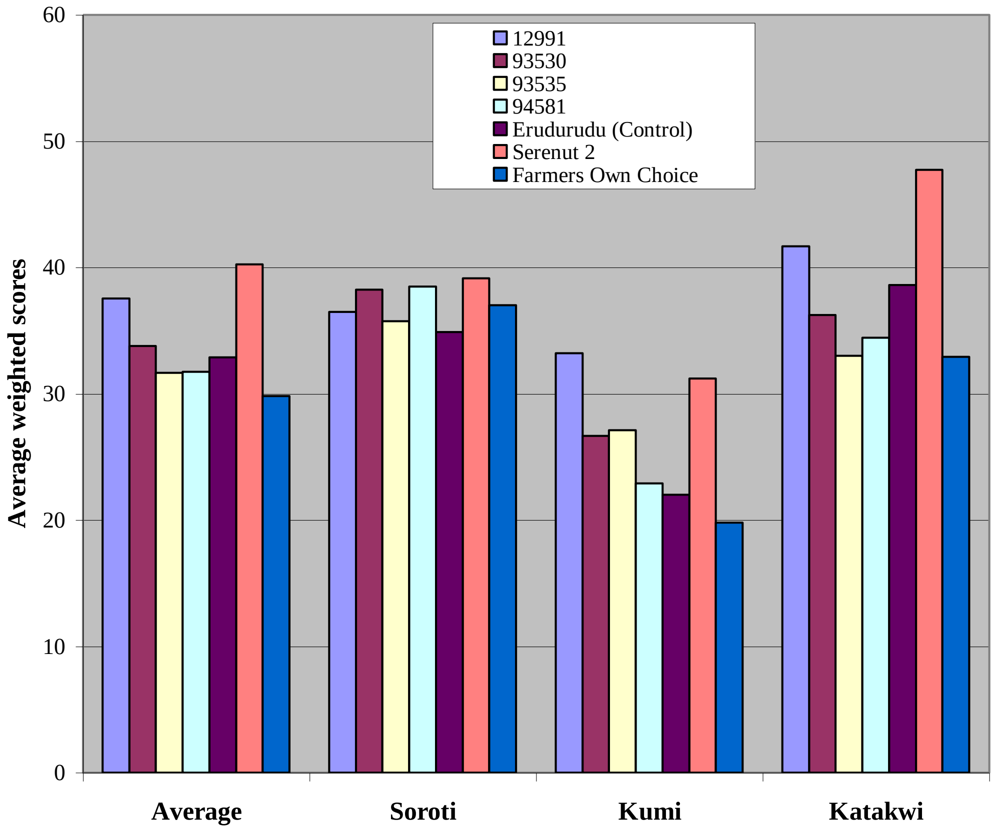


Where V1 = 12991, V2 = 93530, V3 = 93535, V4 = 94581, V5 = Erudurudu (control), V6 = Serenut 2, V7 = Farmers own choice

Farmer scoring of varieties

Figure 9 summarises the information collected from individual farmers on their overall assessment of each variety. These assessments included a wide range of factors identified by both farmers and researchers, and details of these are found in Table 3 and Appendix 28. The overall pattern is very similar to that of yield performance presented in Figures 5 and 6 with Serenut 2 and 12991 performing significantly better than all the other varieties[22]. Figure 10 summarises the results of the farmer group assessments[23] and indicates clearly that Serenut 2 is highly regarded, and scored, by farmers. However the pattern with regard to the new lines is different with smaller differences between them (with 12991 and 93530 equally scored) and with a much smaller difference between them and Serenut 2. Most importantly they all scored much higher than traditional local varieties. There were variations between districts and gender (see Appendix 30) but these are not statistically significant because of the small sample sizes (n=34 for individual assessments and only 6 for group assessments), it is the overall patterns that are more revealing[24].

Figure 9 Average weighted scores - individual farmer assessment

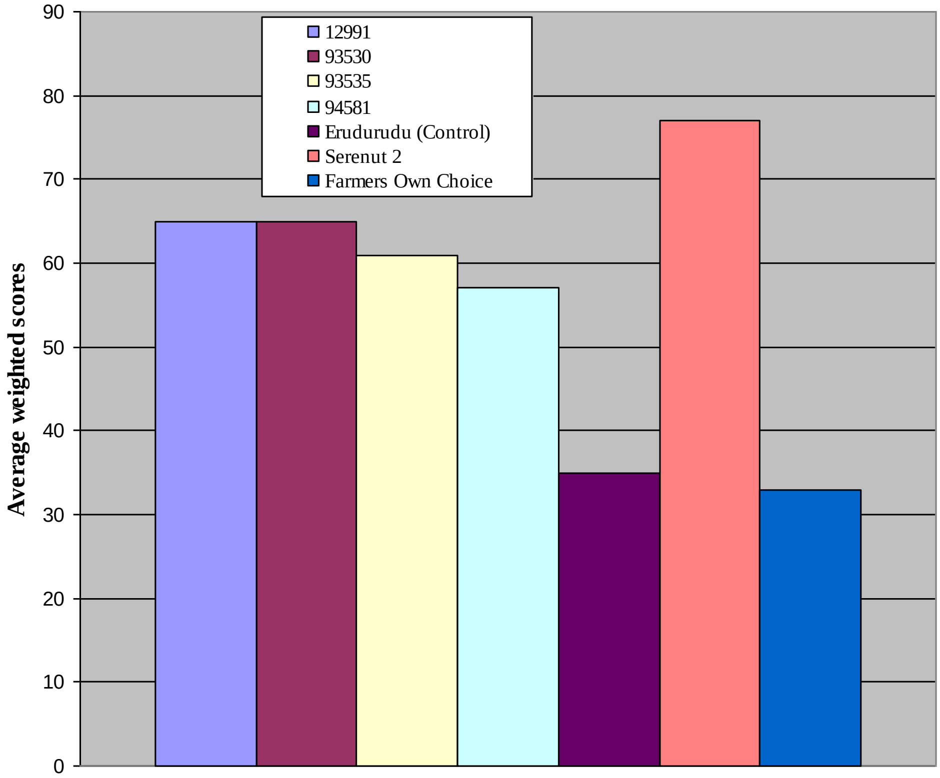


[22] See appendix 28 for more details on the statistics relating to these scores.

[23] All of the farmers for each district were gathered together and then divided by gender. Figure 10 represents the average figures for each of the six groups.

[24] However in broad terms women and men produced scores for each variety that were similar. District variations were also similar to overall patterns (see Appendix 31).

Figure 10 Average weighted scores - farmer group assessments



Conclusion

The main 2001 growing season was somewhat abnormal in terms of very low incidence of rosette disease throughout the Teso area. However even in these circumstances it is clear that the new rosette (disease and vector) resistant lines performed at least on par with both farmers own choices and the local control variety in terms of yield. Within this general pattern two lines were particularly outstanding – Serenut 2 and 12991, out-performing local varieties both in terms of yield and farmers scoring of overall performance. Group assessment exercises scored all the new varieties higher than local controls and farmers' own choices, but the quantitative data, and to a lesser extent individual farmer assessments, in this season did not provide conclusive support for this position.

During visits to the on-farm trials farmers expressed a great deal of interest in 12991 (although for them it was a numbered unknown variety) as it has similar visual characteristics to the locally grown erudurudu and, in fact many were calling it “new erudurudu”. It is likely that when 12991 is bulked up and released that the variety will be taken up rapidly although there is a danger of it being confused with erudurudu, which is susceptible to rosette disease. Care will have to be taken to ensure that farmers are not given or sold the wrong seed.

2.3 Small-scale seed multiplication of selected cultivars for distribution to farmers (year 3).

During the life of the project, all collaborating farmers have been able to keep the seed from the on-farm trials and multiply the different varieties. Thus, 13 farmers in the initial on-farm trials and 57 in the larger scale trials (see section 2.2) have all been able to bulk up the new varieties of groundnut. Some farmers in the initial group have now reached a stage where they are selling the seed or giving it to neighbours. It is interesting to note that on visits to 5 of the initial farmers in July 2001 their plots of IGC12991 were 3-4 times the size of the plots for other varieties. The farmers confirmed that this was due to the high multiplication rate of 12991 compared with the others and not because of preferential planting.

AT (Uganda), SOCADIDO and IDEA have all received seed for bulking up. IDEA were given 60Kg of seed in 2002. AT (Uganda), who are undertaking a CPP/DFID funded project on groundnut seed multiplication, will be purchasing sufficient seed to plant 200 acres of the new varieties from SAARI and its collaborating farmers for planting during first season of each year for the three year project period.

With the assistance of the project, SAARI Oil Seeds Programme have also received funding from CORSU for the bulking of new varieties of groundnut in order to ensure the more rapid dissemination of the varieties.

3.1. Training of at least two national scientists in screening and breeding technologies.

Visits to ICRISAT by SAARI staff
The head of the Oil Seeds Programme for Uganda, Dr Charles Busolo-Bulafu visited the groundnut breeder, Dr Piet van der Merwe, at ICRISAT (Malawi) on two occasions during the project. The first occasion was in March 2000 and second in January 2002. On these visits he was able to study the various techniques used by ICRISAT for groundnut breeding including the use of infector rows, agronomic practices, drying and storage of seed and the selection of breeding lines.

The senior technician of the Oil Seeds Programme for Uganda, Pascal Nalyongo, also visited ICRISAT (Malawi) in December 1999 to undertake training in on-station trial techniques.

Visits to SAARI by ICRISAT and NRI staff
Dr van der Merwe (groundnut breeder, ICRISAT) visited SAARI at least once a year to aid in the training of SAARI staff, extension staff, collaborating NGO's and farmers in the various aspects of groundnut breeding. He also helped to write the Groundnut Manual which has contributed to knowledge and training of people in Uganda.

Dr Frances Kimmins (former project leader), Dr Duncan Overfield (socio-economist), Bill Page (entomologist), Dr Tim Chancellor (project leader), Dr David Jeffries (biometrician), all of NRI, have ensured that at least bi-annual visits have taken place to the Teso area in order to interact with the SAARI groundnut breeder, entomologists, social scientist and technicians, NGO personnel, district agricultural officers and collaborating farmers to provide them with information on appropriate technologies for seed production, storage, on-station disease screening trials, disease symptomatology, vector monitoring, assessment of vector resistance, experimental design, participatory farmer surveys and data analysis. As well as on station and on farm training more formal seminars were held at SAARI for all staff and invited guests in order to inform and disseminate information on the project. The following seminars were given:

20 September 2000 (22 people attended)

Use of vector resistance for management of groundnut rosette disease. Frances Kimmins

22 January 2001 (26 people attended)

1. Biometric review of on-farm trials: planning, design, analysis and management. David Jeffries
2. The groundnut leaf miner. Bill Page

24 September 2001 (30 people attended)

Use and application of the groundnut household survey database

3.2. One Ph.D student trained in determining the genetics of vector resistance in selected groundnut lines.

The work described in this section was undertaken by a PhD student Ms Liezel Herselman who has been based at the South African Agricultural Research Council's Grain Crops Institute, Potschefstroom, with liaison visits to ICRISAT (Malawi) and NRI. Supervision, training and liaison visits were undertaken by Dr P van der Merwe (ICRISAT), Dr C Mienie (GCI), Dr RA Naidu (Department of Plant Pathology, University of Georgia, USA) and NRI staff. This work is due to finish on 31st March 2003.

Background

Host-plant resistance is considered to be the most cost-effective and practical management measure against rosette disease. Field screening trials in Malawi have identified several groundnut genotypes that are rosette resistant; some are resistant to one of the virus components in the disease complex, but others are thought to be resistant to the aphid vector. There is a clear need to characterise the vector resistance in order to enable this trait to be used effectively in groundnut improvement programmes. This study is intended to contribute to this aim.

Results throughout the world have indicated that molecular work on cultivated groundnut presents a big challenge. Basic genetic research on groundnut has not progressed as rapidly as it has in many other crops. This is partly due to the limited acreage devoted to domestic groundnut production, as compared to other major agronomic crops, and the relative importance of groundnut as a staple crop only in less developed regions of the world. As a result, little information is available on the molecular biology or evolutionary history of groundnut.

Although considerable levels of morphological variability have been observed among the germplasm resources of cultivated groundnut, very little genetic polymorphism has been detected within groundnut using molecular markers. In an evolutionary nascent species like cultivated groundnut, it is likely that simple nucleotide substitutions, rather than gross differences, account for variation among genotypes. Molecular marker research on various groundnut species has yielded interesting results in several fields of research. Genetic variability studies using isozymes, restriction fragment length polymorphisms (RFLPs) RFLPs, random amplified polymorphic DNA (RAPDs), amplified fragment length polymorphisms (AFLPs) and microsatellite analysis have shown that domesticated groundnut has a low level of genetic variation in contrast to the abundant variability found among various wild species. This level of variation affects the ability to perform linkage analysis. The amplified fragment length polymorphism (AFLP) technique is more effective in detecting single nucleotide changes (at sites for restriction and selective amplification) compared to RFLP and RAPD procedures. Work done at the Agricultural Research Council–Grain Crops Institute (ARC-GCI) in South Africa indicated that the AFLP technique could be successfully used for the identification of polymorphisms in cultivated groundnut and is being used in this study to search for molecular markers linked to groundnut rosette disease.

Objective

The main objective of the study is to identify molecular markers linked to the single recessive gene conferring aphid vector resistance. Generated data is being used to construct a genetic linkage map and to map the position of the single recessive gene.

Methods and outputs

An F2 population derived from a cross between an aphid-resistant female parent and a susceptible male parent was developed, planted and evaluated for rosette resistance in greenhouse trials at ICRISAT (Malawi). Phenotypic evaluations of the F2 population were confirmed using reverse transcription-polymerase chain reactions (RT-PCR). All three agents for the disease were detected in lines in the susceptible bulk and none of the virus complex components were detected in the lines used in the resistant bulk.

AFLP analysis was employed as a molecular marker technique in combination with bulk segregant analysis (BSA). AFLP analysis was done using the kit supplied by Life Technologies Inc. and gels were stained using the Silver Sequence™ DNA Sequencing System kit supplied by Promega. Using 64 available primer combinations, 4336 fragments were amplified in the genomes of the parent lines and the two bulks. A total of 74 fragments were polymorphic between the two parent lines and only 27 polymorphic between the two bulks (amplified with 13 primer combinations). These 13 primer combinations were tested on the 12 individual plants from the bulks and four revealed informative polymorphisms. These informative primer combinations were tested on 40 individual plants of the F2 population but no molecular marker for rosette disease was identified.

AFLP analysis detected a very low level of polymorphism between parent lines (1.7%) as well as the two bulks (0.6%). To date, very little genetic polymorphism has been detected with molecular markers within *Arachis hypogaea.* The low DNA polymorphism in cultivated groundnut, in contrast to the high diversity for agronomic traits, may be due to the selective neutrality of molecular markers, while morphological traits have been subjected to intense selection**.**

To ensure that the segregating F2 population used for marker selection analysis arrived from a cross between the resistant and susceptible parent, and not from a self-pollination event, the authenticity of the F2 population was verified using an existing microsatellite marker Ah4-26. The inheritance pattern of the microsatellite marker verified the authenticity of the 12 individuals of the F2 population used in BSA.

The AFLP technique uses two enzymes, a rare cutter and a frequent cutter. Based on results obtained after cutting groundnut DNA with different enzymes, AFLP analysis was performed using either *Eco*RI or *Mlu*I as rare cutters in combination with *Mse*I as frequent cutter. A total of 208 primer pair combinations were tested on the parental lines and bulks. Primer pairs revealing informative polymorphisms between the parents and bulks were tested on the twelve individual lines of the bulks. Primer pairs that explained a 40% or higher variation for groundnut rosette disease in the individuals were tested on 40 individuals of the segregating population. Results indicated that AFLP analysis was efficient in detecting polymorphisms in groundnut although a low level of polymorphism was revealed. The low level of polymorphism correlated well with data from literature. Although the *Eco*RI/*Mse*I approach detected more fragments per primer pair, the *Mlu*I/*Mse*I approach detected more polymorphisms per primer pair. The two AFLP approaches detected 29 informative polymorphic loci in the 40 individuals of the F2 population that could be used for statistical analysis of the data.

Data was analysed statistically using MAPMAKER/EXP and MAPMAKER/QTL software programmes. Using MAPMAKER/EXP a very basic genetic linkage map for cultivated groundnut was constructed based on the 29 informative loci. Four linkage groups were identified. Although a few reports of linkage between various morphological traits exist in literature no linkage groups or genetic maps based on molecular marker evaluations have been reported. ***It is believed that this basic map generated at the ARC-GCI represents the first linkage map for cultivated groundnut***.

Data obtained from constructing the genetic linkage map was used for the identification of putative QTLs linked to groundnut rosette aphid resistance. A single recessive gene, explaining 100% of the variance in aphid resistance in the segregating population, was mapped to Linkage group 2. ***This result confirmed results from inheritance studies that indicated that a single recessive gene governs aphid resistance. Although two markers flanking the recessive gene were identified, these markers were not linked close enough to the gene to be useful in breeding programmes***. Future research will focus on the search for markers that are more closely linked to the gene and the extension of the existing genetic linkage map for cultivated groundnut.

4.1 Understanding the nature of aphid resistance and developing a screening methodology for such resistance for easy identification in the field.

Most of the work in this section has been undertaken as part of an HEFCE funded PhD studentship by Mr Jeroen Willekens, who has been based at NRI with liaison visits to SAARI and ICRISAT (Malawi). Supervision, training and liaison visits have been undertaken by Dr P van der Merwe (ICRISAT), Dr RA Naidu (Department of Plant Pathology, University of Georgia, USA) and NRI staff. This work is due to finish on 30th September 2002.

In field trials, several cultivars show low disease incidence because they are resistant to the aphid vector rather than rosette disease. Preliminary studies suggest that this resistance operates by preventing the aphid from feeding. The purpose of the PhD studentship is to study aphid behaviour on these resistant lines along with microscopic and chemical analyses of plant tissues.

Field trials on vector resistant cultivars

Under laboratory conditions at NRI, it was shown that in no-choice tests the resistance of ICG12991 caused an increased duration of aphid development, a decreased fecundity of adult apterous aphids, an increased mortality of instars and when exposed in choice tests, non-preference or antixenosis for ICG12991 was observed. In view of the artificial conditions under which the evaluations were conducted in the laboratory, these adverse effects on aphid biology and behaviour on this variety needed to be assessed in the field in order to confirm the usefulness of the resistance. Under laboratory conditions, plants of all varieties tended to have a more erect growth habit it was not known what effect this and other factors might have on the level of expression of resistance in different groundnut varieties.

1. Screening of 10 different groundnut varieties by *A. craccivora* in the field in Uganda

In order to examine the vector resistance/preference of different varieties under field conditions four replicates of 10 groundnut varieties were planted in a randomised block design. A plan of the arrangement of the field plots is shown in Table 15. The groundnut varieties were labelled A-J and until final analysis it was not known which variety was linked with which letter. Each plot consisted of 6 rows of groundnuts, 5 metres long and 45 cm apart. A path of 30 cm was left between the plots. A guard row was planted around the trial, 60 cm away at the sides and 30 cm at the ends. In total 20 plants per variety per replicate were sampled in a randomised manner for numbers of aphids and aphid colonies. Aphid counts were carried out every other day for 10 days, so that 8000 plants in total were sampled. For each variety a mean percentage of germination was also calculated.

Table 15. Plan showing the arrangement of the field plots (variety in brackets).

Replicate 1	Replicate 2	Replicate 3	Replicate 4
J (Igola 2)	D	C	B
I (93557)	A	E *	G
H (94584)	B	F	H
G (Red Beauty)	C	D *	A
F (12991)	G	B	J
A (93530)	H	G *	I
B (93535)	I	H	D
C (93524)	E	A *	C
D (94581)	F	J	E
E (99540)	J	I	F

*:Position of rain-gauges

Figure 11 shows the total numbers of plants on which at least one aphid was recorded during the 10-day sampling period. Three varieties ICG12991 (F), ICG-SM 99540 (E) and ICG-SM 93535 (B) were the least infected plants. The highest numbers of infested plants were found on ICG-SM 93524 and the lowest number on ICG12991. A general increase in infested plants (plants with at least one aphid) over time was observed for all but three varieties; ICG12991, ICG-SM 99540 and ICG-SM93535 (Figure 12). ICG12991 was the only variety where no colonies of aphids were found. This variety also had a high germination of 98.8 %. (Table 16).

Figure 11. Total number of plants with at least one aphid during a 10- day sampling period. The number above each bar represents the order of most infestation to lowest infestation.

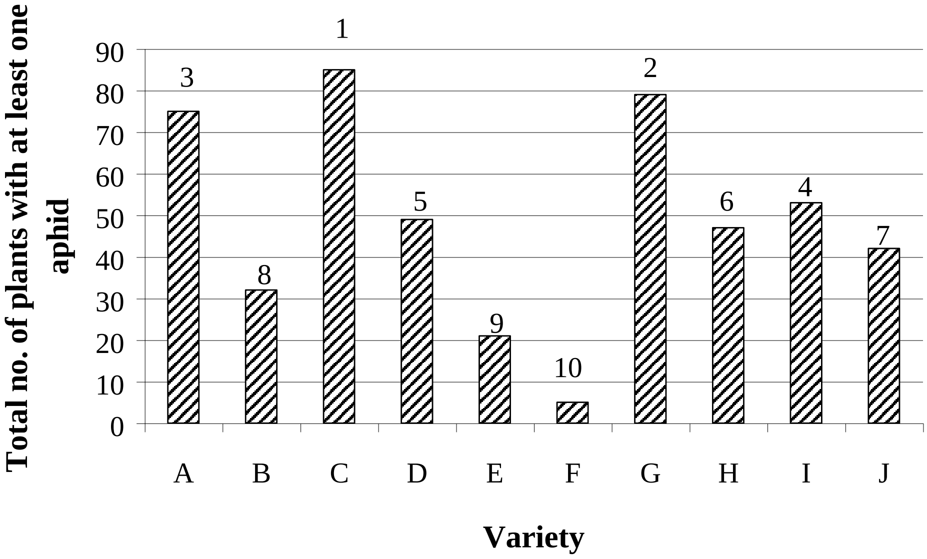


Figure 12. Number of plants with at least one aphid per sampling day. The number above each bar represents the order of most infestation to lowest infestation.

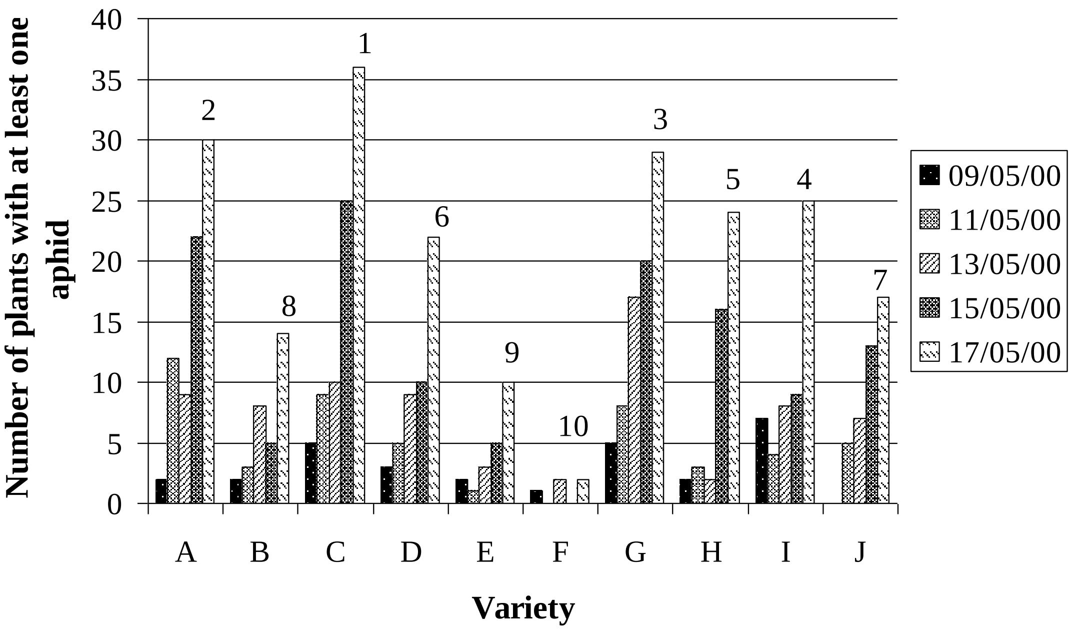


Table 16. Mean germination (%) of 10 groundnut varieties screened for aphid infestations based on measurements taken on 19/05/2000.

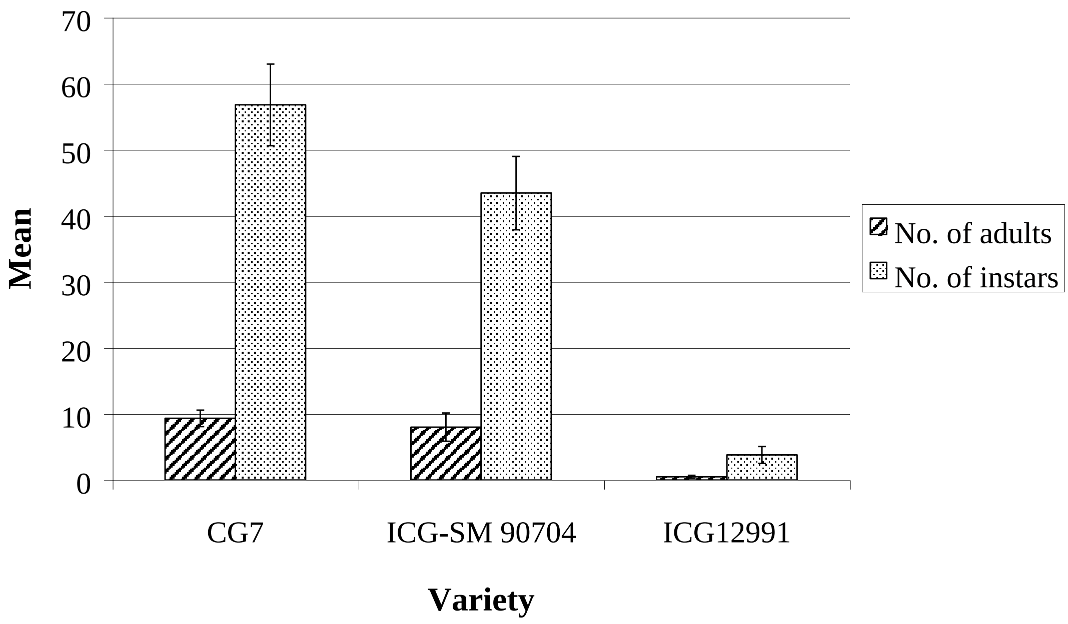
Variety ICG	**Mean % germination**
93530	95.0
93535	76.3
93524	97.5
94581	93.8
99540	97.5
12991	**98.8**
Red beauty	**98.8**
94584	92.5
93557	67.5
IGOLA II	90.0

2. Acceptance of 3 different groundnut varieties by apterous *A. craccivora* in a no-choice experiment in the field in Uganda

A no-choice experiment was conducted after an aphid colony was established in the glasshouses at the experimental site of SAARI- Uganda (13/05/1999 – 19/05/1999).
The test plants were spread over three rows and three different groundnut varieties were chosen for the experiment. These varieties were ICG-SM90704, ICG12991 and CG7. A single apterous aphid per plant (28 DAP) was used as previously under controlled conditions at NRI. Ten plants per variety were used and two perforated cellophane bags covered each plant. The first cellophane bag was used to cover the top of the plants to keep the aphids on the plants and the second one covered the whole plant to prevent natural aphid infestation during the course of the experiment. The covered plants were also protected from heavy rain by polystyrene tiles. The adults were left on the plants for 6 days, after which the tiles and bags were removed. The top of each plant was then removed and placed in a vial, filled with 70% alcohol. The number of instars and adults per plant was then counted in the laboratory. Means were compared with ANOVA in GENSTAT 4.1

Significantly fewer adults ($P<0.001$) and instars ($P<0.0001$) were found on ICG12991 after 6 days compared to CG7 and ICG-SM 90704 (Figure 13). Only 2 adult aphids out of 10 managed to form small colonies of around 10 instars on ICG12991 and only one instar reached the adult stage. On CG7 a mean of 57 $\pm$ 6 instars per plant were produced and 43 $\pm$ 6 instars on ICG-SM 90704. A total of around 10 adult aphids were found on these two varieties. The mean number of growing points on CG7 and ICG-SM 90704 was 6 compared to 5 on ICG12991 and the mean height of the plants of the former 2 varieties was 15cm compared to 18cm for the latter.

Figure 13. Mean number of adults and instars on three groundnut varieties when one adult apterous aphid was left for 6 days. Number of replicates is 10 for all three varieties.



3. Acceptance of 3 different groundnut varieties by apterous *A. craccivora* in a choice experiment in the field in Uganda.

Three varieties were compared, ICG-SM 90704, ICG12991 and CG7 using one adult apterous aphid per plant from culture. The varieties were planted in plots of 6 rows over 5 metres. The plants were marked in the field and inspected for colonies 48h after the introduction of the adult. The plants were left naturally without any protection from ambient conditions. The experiment was repeated twice (n=2 x 9 for each variety) with an interval of two days between trials. A Student's T-test was applied to compare numbers of instars on CG7 and ICG-SM 90704.

No colonies were found on any of the 18 plants of ICG12991 whereas colonies were found on seven plants of CG7 and eight plants of ICG-SM 90704 (Table 17). The mean number of instars per colony was 11 on CG7 and 6 on ICG-SM 90704. No significant difference for the number of instars per colony found on CG7 and ICG-SM 90704 was noted.

Table 17. Choice experiment evaluating three varieties where one adult apterous aphid (*A. craccivora*) was placed and left for 48 hours.

Variety	**CG7**	**90704**	**12991**
No. of colonies	7	8	0
Mean no. of instars/colony	11	6	0
Mean plant height (cm)	15	14	18
Mean no. of gps/plant	7	8	6

Gps = growing points of the plant.

4. Screening of three groundnut varieties (JL24, ICG12991 and ICG99540) under high pressure of viruliferous aphids (*A.craccivora*) using the infector row technique at ICRISAT Malawi

Aphid counts were conducted on five occasions over a period of 10 days, according to suitability of the weather, in a field trial at the ICRISAT research station in Malawi. The field trial was designed in an 8x8 lattice and replicated three times. In total, 64 varieties were planted in plots of 3 rows x 6m x 0.6m, with a seed spacing of 10cm and 200 seeds of each variety. Three varieties out of the 64 were screened for aphids and aphid colonies and 20 plants were randomly chosen per variety per replicate. The plants were at the flowering stage (40 DAP) and additional information about the plant growth such as plant height and number of growing points were recorded on the last day of sampling. Because of unfavourable weather conditions not all the experimental work for all the replicates could be conducted during each trial. All three replicates for all 3 varieties were sampled on 09/01/2001, 15/01/2001 and 18/01/2001. On 11/01/2001, only replicate 3 was considered prior to heavy rains. On 12/01/2001 two replicates were completely sampled for JL24 and ICG12991, whereas 75% in one replicate was sampled for ICG-SM 99540. Aphid colonies were counted and the location specified on leaf tissue versus flower tissue. A colony was considered when at least two aphids from any stage were present together. The number of aphids was than ranked in an order of magnitude: 1 = 1-10, 2=11-100, 3 = 101-1000, 4 = >1000. The percentage of plants containing at least one colony of aphids and the proportion of colonies found on flower tissue or leaf tissue were calculated.

More plants were infested with aphid colonies on JL24 than on ICG12991 and ICG-SM 99540 (Figure 14). An increase in infestation could be noted for all three varieties from the first to the second sampling dates. On the 3rd sampling day, a strong reduction of infested plants was noted on ICG12991 and ICG-SM 99540, whereas 100% infestation was recorded on JL24. At the end of the sampling period a general decrease in infestation was observed on all varieties. Looking at the proportion of colonies located on flower tissue (Figure 15), a large difference could be noted between JL24, ICG12991 and ICG-SM 99540. Only a low proportion (5%) of the colonies was found on the flowers of JL24 and this remained stable during the sampling period. By contrast, on plants of ICG12991 the proportion of colonies on the flowers was the highest for all sampling days reaching a maximum of 71%. Also a high proportion of colonies on the flowers of ICG-SM 99540 was observed reaching a maximum of 35%. For the latter two varieties the proportion declined strongly with time and at the last sampling day (18/01/2001) no colonies were found on the flowers of any variety tested.

Figure 14. Plants with at least one aphid colony (%) under high pressure of aphids (*A. craccivora*) per sampling day.

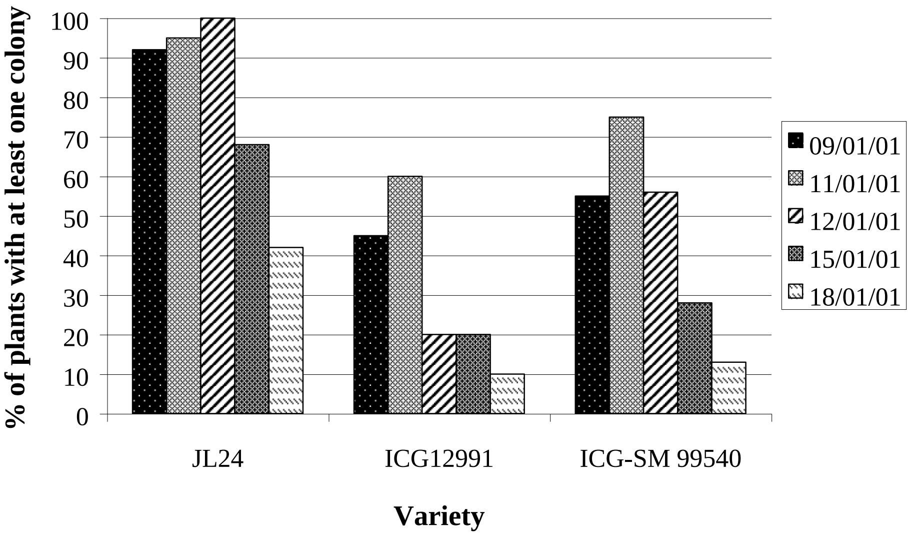
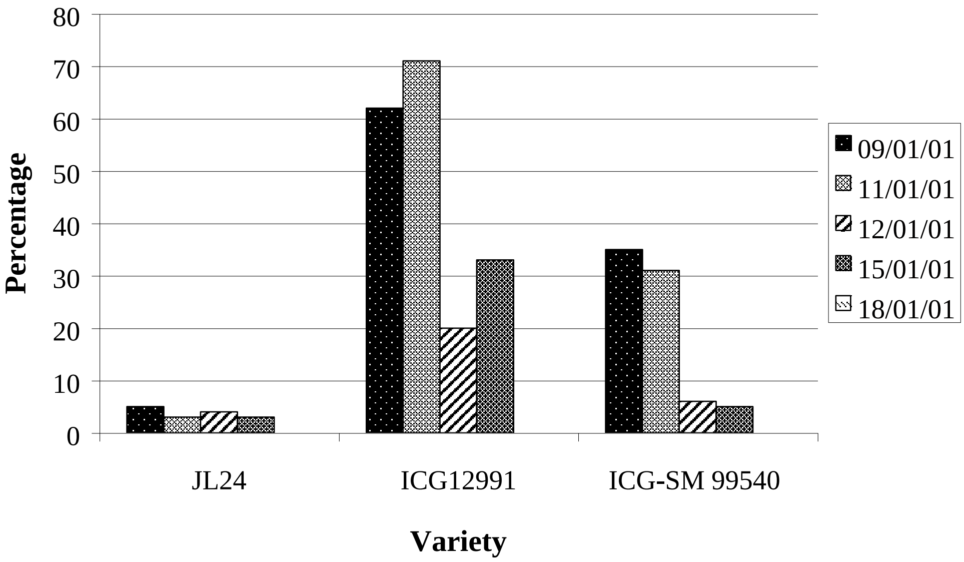


Figure 15. Proportion of colonies per sampling day found on flower tissue of three different groundnut varieties.



4. Conclusions

In these field trials and in previous laboratory experiments (Willekens pers. comm.) it has been shown that the confinement of aphids on plants of some groundnut varieties, particularly ICG12991, results in delayed instar development, reduced survival, lower bodyweight and reduced fecundity of adult aphids. These responses were generally stronger on older plants (28DAP) than on seedlings (7DAP). Such plant characteristics with an adverse effect on the insects' survival, longevity and fecundity can be termed as antibiosis. In addition it has been shown clearly in the above experiments that 12991, and some other varieties, show antixenosis (non-preference) which denotes plant characteristics and insect responses that direct an insect away from a plant. In the field, both in Uganda and Malawi, the results suggest that aphids (particularly alates), will not stay long on such varieties. It is important to note, however, that feeding and colony establishment can occur on the flower stems which are present for a short time during the growth of groundnut. If these varieties do get GRD infections it will most likely be at the flowering stage.

Work has also been carried out on the virus transmission in vector resistant varieties and combined with the results on aphid behaviour could explain the low GRD infection in 12991 on the screening trials at ICRISAT-Malawi. Aphids land on the plants but leave the plant at a very early stage. If instars are deposited on the plants by incoming alates at least half of them will not survive to adulthood. Those that do survive struggle to feed, leading to reduced fitness and failure to successfully transmit the virus agents to new plants. Aphids can adapt to these conditions but the resistance is not broken down. Therefore the infection as seen in the field is likely to be primarily caused by incoming viruliferous aphids rather than by secondary spread.

Work on the nature of vector resistance

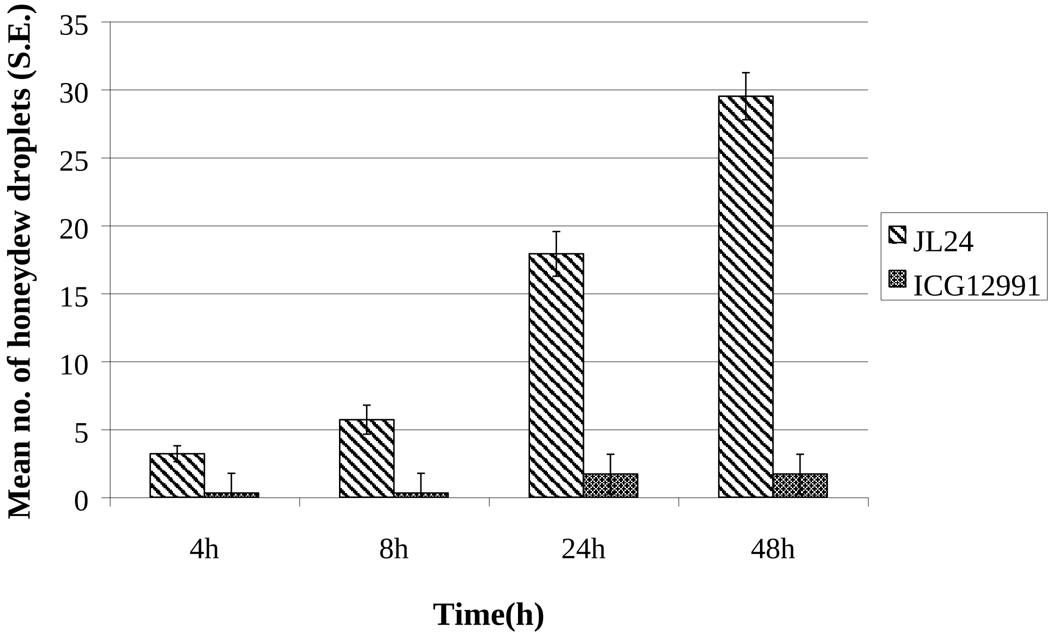
Both field and laboratory experiments showed adverse effects on aphid biology when exposed to leaf tissue of groundnut variety ICG12991. Field observations showed aphid colonies were generally present on flower tissue of ICG12991. Further laboratory tests showed no inhibition of feeding when aphids were placed on the flower stems of resistant and susceptible groundnut varieties. Measuring honeydew droplets produced over time was used to test this. It was shown that over 24 hours an equal amount of honeydew was produced on the flower stems of both varieties (Figure 16a). The average diameter of the droplets was 1mm. By contrast, almost no honeydew was produced on the leaf tissue of ICG12991 and the diameter was generally lower than on JL24 (Figure 16b). Electric recording of the feeding behaviour over a 4h period showed that aphids did not manage to have sustained ingestion from the phloem sieve elements (E2) on ICG12991 (Table 18). Time of pathway activity (c) was also significantly increased suggesting difficulty in locating the phloem. However the time to first salivate into the sieve elements from the start of the experiment or from the start of a probe did not differ significantly. It must be noted that within 4h only 65% of the aphids were able to salivate into the sieve elements (E1) on ICG12991, whereas 80% of the aphids were able to do this on JL24.

Table 18. EPG recording of aphid feeding on leaf tissue of two groundnut varieties (JL24 and ICG12991). Plants were 14 DAP. Parameters in minutes (mean ± S.E) are non-penetration time (np); pahtway activity (c); salivation into the sieve elements (E1); time from start of a probe to reach E1; time from start of experiment to reach E1and sustained ingestion from phloem (E2).

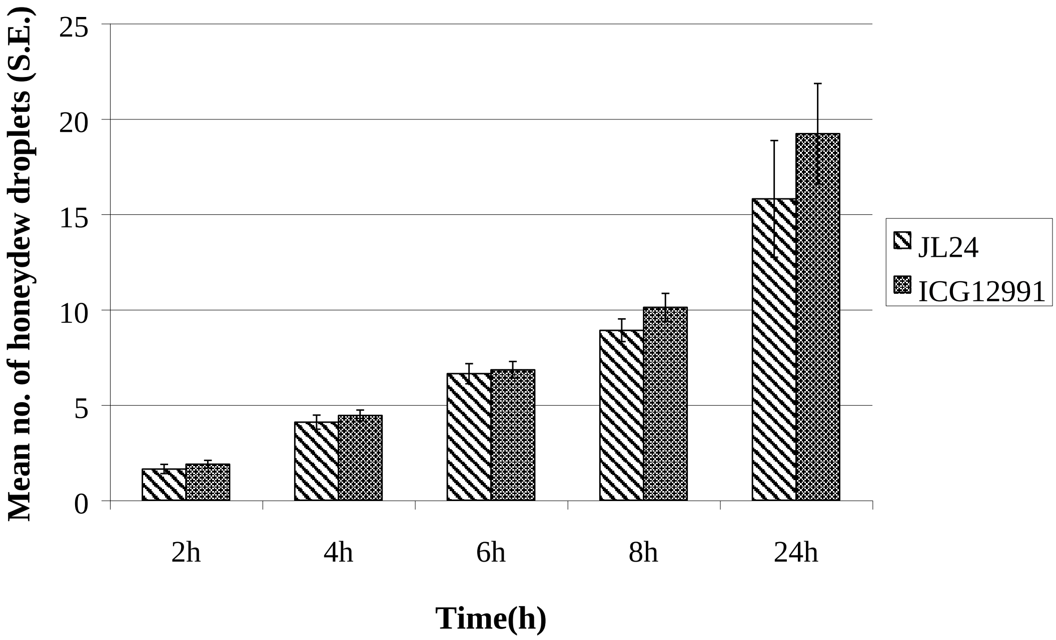
	JL24	**ICG12991**
np	94.3 ± 19.3	83.8 ± 9.4
c	70.4 ± 13.5	136.7 ± 8.2
Probe-E1	14.2 ± 3.6	16.5 ± 2.6
Start-E1	97.2 ± 43.3	152.3 ± 20.1
E1	5.1 ± 2.8	4.5 ± 1.3
E2	118.3 ± 55.3	*

Figure 16. Number of honeydew droplets produced per aphid on leaf tissue of two different groundnut varieties (JL24 and ICG12991)

a) Leaf tissue



b) Flower stems



Two techniques based on artificial diets were tested for possible location of deterrent effects of leaf tissue extracts of ICG12991 on aphid probing behaviour. The first method was based on a solution pressed in between two parafilm membranes, referred to as “sachet technique” and the second was based on an agarose gel. Both techniques were first tested by applying a known phagostimulant (sucrose 20%) and known antifeedants (Pymetrozine and Neem extract). Both methods detected a difference in number of probes and length of probes over an 18h experimental period. When water based extracts of leaf tissue were applied in both bioassays probes were generally longer when extracts were diluted. The deterrent effect was likely to be caused by a range of deterrent chemicals such as phenolics present in leaf tissue. However there was no difference between the two varieties. Flower stem extracts were also applied. Although the original concentration could not be tested, an increase in probes and longer probes were observed. Again there was no difference between the two varieties.

Based on the above studies there was little evidence for a constitutive presence of antifeedant chemicals in ICG12991. However it has been noted that leaves of varieties with vector resistance, exposed to aphids, showed a deposition of phenolics at the feeding sites. The deposition was noted after 24h. The hypothesis of induction of resistance is therefore being tested.

Establishing a screening methodology for identifying vector resistance in the field

During the studies described above it has been shown that, under field conditions, ***it is possible to identify vector resistance on varieties by the comparative lack or degree of aphid colony establishment***. This method works both under natural infection conditions (Uganda) and even under very high pressure as under the breeding trial conditions at ICRISAT. By introducing such a method into routine monitoring of groundnut trials it would be possible to identify good vector resistant varieties and even degrees of vector resistance.

5.1 Production of a groundnut manual for the Teso farming system

A 20 page manual entitled "Groundnut Manual for Uganda – Recommended groundnut production practices for smallholder farmers in Uganda" was compiled by project staff and presented to the collaborators at the stakeholder workshop held on 13th March 2002. The manual covers the main aspects of groundnut production: land selection, land preparation, planting, weeding, main diseases and pests, phenology, harvesting, drying, storage, shelling, aflatoxin, quality and marketing. A sleeve in the back of the manual is provided for inserting up to date information on the groundnut varieties available and their qualities.

A copy of the manual in electronic form is attached in the CD provided.

6.1 Additional activities and outputs: identification and initiation of studies of groundnut leaf miner, a new pest to the Teso groundnut system.

This additional activity was developed from farmers' queries and requests for information about a new groundnut pest. One of the important features of introducing rosette disease and vector resistant varieties of groundnut into the Teso farming system was to release farmers from the costs and hazards of spraying with insecticides to kill the aphid vectors of the disease (often four sprays in a season). The appearance of the leaf miner in the area now produces a new constraint which, at present, can only be controlled by individual farmers using insecticides.

Samples of the new pest, collected by project staff from Soroti in 1998, were identified by the Natural History Museum, UK as being *Aproaerema modicella* (Deventer)(Lepidoptera: Gelechiidae) the groundnut leaf miner known from India and the Far East. As far can be ascertained, this was the first record of this species in Africa. In view of this, efforts were made to collect information on the appearance and perceived incidence of the leaf miner in the area from local farmers, agricultural officers and scientists. GLM damage was first reported in Kumi District in the first planting season of 1997, and was recorded in Kumi and Soroti later during the second season (September 1997 – January 1998). During 1998 the miners were reported from Kumi and Soroti Districts, in the south eastern part of Katakwi District and the northern part of Pallisa District, both of the latter areas being adjacent to Kumi District. In the first and second seasons of 1998, farmers and extension officers reported large outbreaks of leaf miners causing considerable damage and there was an increased use of insecticides in order to try and reduce the problem. Many farmers had complete crop losses due to miner damage during this period. GLM has also now been recorded in Iganga, Apach, Lira, Katakwi, Masindi and Hoima Districts. Elsewhere in Africa the leaf miner was reported for the first time from Malawi in April 2000.

The sudden appearance of groundnut leaf miner in the central Districts of Uganda posed a number of questions. Firstly, the knowledge gathered initially on the distribution of the pest suggested that the distribution might have been confined to a particular area. It was therefore important to identify more precisely what the pest's distribution was using pheromone traps, visual surveys and farmer/agricultural office surveys both within the known area as well as elsewhere in Uganda. Secondly, it is not known yet whether the leaf miner would be able to maintain numbers to remain as a pest or whether unusual weather conditions allowed a build up in 1997 and 1998 that may not occur on a regular basis. Once these answers have been established it may be possible to identify whether this pest has the potential to spread elsewhere or whether it can be controlled or eradicated in order to stop further spread. ***Project staff therefore assisted the Senior Entomologist at SAARI, Dr G Epieru, to develop a project entitled "Participatory evaluation of the status, distribution and management of the groundnut leaf miner in the Teso and Lango, farming systems" funded through CORSU and this study is currently under way***.

A short paper entitled "The groundnut leaf miner (*Aproaerema modicella*, Deventer): a new pest in eastern Districts of Uganda" by Page, *et al* (2000) was published in the Arachis Newsletter.

Contribution of Outputs to Developmental Impact

The outputs developed and promoted by the project have contributed significantly to the goal of developing and promoting improved disease control strategies for groundnut production in the Teso system in Uganda. In a wider context, the outputs will assist a substantial number of smallholder farmers to increase their income. This will be achieved primarily through the availability of new short-duration, disease-resistant groundnut varieties that were produced in the project. In parallel with these improved varieties, new knowledge generated by the project is being disseminated through several means, including a groundnut production manual.

Considerable attention has been devoted during the project to enhancing institutional capacity within Uganda to help ensure that the gains made from the research will be sustainable. At one level, training and informal knowledge transfer in appropriate disciplines has enhanced the capability of SAARI scientists to conduct high quality research. By forging strong links between SAARI and ICRISAT in Malawi, this research capability will be maintained in future years to the benefit of groundnut improvement programmes in Uganda. The project has also identified an important new researchable constraint, the groundnut leaf miner. Project staff assisted SAARI researchers to develop a research proposal that has been funded by the DFID Client-Oriented Agricultural Research and Dissemination project.

The second means by which institutional capacity has been enhanced is through the establishment of a self-sustaining system of groundnut seed multiplication and distribution. This involves the creation of linkages between government and non-government agencies. A key feature is the role played by NGO's in delivering seed to farmers who stand to benefit most from growing it. One of the project collaborators, AT (Uganda) has successfully applied for additional funding to facilitate the farmer to farmer transfer of new rosette-resistant groundnut varieties through an innovative approach. It is anticipated that by the end of this three-year project a total of 9,000 farmers will have participated in seed multiplication, leading to the production of 1100 mt of groundnuts. In addition, 2,000 farmers will have received training in seed production and storage.

Groundnut rosette disease is a serious constraint to groundnut production in West Africa. It is believed that the impact of the project could be further developed through the application of a similar approach to that taken in Uganda. Consequently, it is planned to develop a research proposal involving the international partners and institutions in West Africa to conduct a two-year programme to evaluate and promote rosette-resistant varieties.

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Appendix 1 – Survey questionnaire

NATIONAL AGRICULTURAL RESEARCH ORGANISATION

Questionnaire on

GROUND NUT ROSSETTE DISEASE AND ITS MANAGEMENT SAARI/NRI

Start time: .... End time: .... Code No. : ....

Name of enumerator: ………………..………….. Date: ....

A. HOUSEHOLD AND SOCIO-ECONOMIC CHARACTERISTICS

Name of Respondent:……………………………… District: ....

Age of household head …………Years County: ....

Sex of household head 1= Male, 2=Female Sub-county: ....

Parish: ....

Village: ....

1. (a) Formal education (highest Level attained)
   - i) Illiterate ____________________ 0
   - ii) Primary school
   - iii) Secondary school - S4 / Junior school (J3)
   - iv) High school - S6 / J5 / technical school / TTC
   - v) More than S6 - University / higher TTC

1. (b) If female, where is the husband
   - Not relevant _________________ 0
   - Dead _______________________ 1
   - Divorced ___________________ 2
   - Other ______________________ 3

1. (c)Marital status

i) Single
ii) Married
iii) Other(specify)

2. (a) Size of production unit
   - i) Total acreage …………………. acres
   - ii) Cultivated area …………………. acres
   - iii) Grazing area …………………. acres
   - iv) Area under fallow …………………. acres

2 (b) Tenure of land (Give acreage)

i) Communal …………………. acres
ii) Private …………………. acres
iii) Government / institutional …………………. acres
iv) Family / clan …………………. acres

2. (c) Did you rent/hire in land? Yes ____1 No _____2 (if yes specify acres)
2 (d) Did you rent out land? Yes ____1 No _____2
2 (e) Did you give land for share cropping Yes ____1 No _____2
3. (a) How long have you been farming? …………………. (years)
3. (b) Do you farm part-time or full time?
   - (i) Part-time
   - (ii) Full time

3. (c) If you are not a full time farmer, how much of your time do you devote to farming operations? (tick the appropriate)

(i) less than a half
(ii) half
(iii) more than a half

4. (a) Is any member of your household involved in any off-farm activities? (i) yes (ii) no

4. (b) If yes, please specify the activity(ies)

(i) formally employed
(ii) making baskets, winnowers,
(iii) trading / business
(iv) hiring out oxen/farm implements/labour
(v) others (specify)
(vi) Is anyone else in the household who does not live there involved in any off-farm activities? (Capture influence of remittances).

5. (a) Which types of livestock are kept in the household. (Give numbers)

Livestock Type	Number	Ownership
Cattle		
Goats		
Sheep		
Donkeys		
Chicken		
Pigs		
Turkeys		
Other (specify)		

*(men=M; women=W, C=children)

5. (b) Give 5 of the major crops that are usually grown in the first season, who grows it and the purpose of production:

	Crop	**Acreage**	**Gender***	**Purpose of production****
1				
2				
3				
4				
5				

*(men=M/women=W)
**(1=Cash generation, 2=food - subsistence, 3=brewing, 4=other(specify), …)

5 (c) Give 5 of the major crops that are usually grown in the second season, who grows it and the purpose of production:

	Crop	**Acreage**	**Gender***	**Purpose of production****
1				
2				
3				
4	-			
5				

**(1=Cash generation, 2=food - subsistence, 3=brewing, 4=other(specify), …)
Be careful to capture multiple objectives.

5. (d)How much of the crops listed in question 5(b and c) did you sell last year?

Crop	**Qnt. produced (bags/tins/basins/kg)**		**Amount sold (bags/tins/basins/kg)**		**Price* (ushs/kg)**	
	1st season	**2nd season**	**1st season**	**2nd season**	**1st**	**2nd**

Crop	**Qnt. produced (bags/tins/basins/kg)**		**Amount sold (bags/tins/basins/kg)**		**Price* (ushs/kg)**	

**Prices to be converted properly*

B. LABOUR

6. (a) What family labour is available for production activities?

Age group	Participating in farm activities all the time		Not directly participating in farm activities (part time)	
	Male	**Female**	**Male**	**Female**
18 & above				
12 - 17 years				
7 - 11 years				
6 and less				

6. (b) Do you use hired labour? (1) yes (2) no
(c) If yes , specify for which crops

6. (d) What kind of hired labour do you use per season *(on average or last season: Number of days as well)?*
i) First season

Type of hired labour	No. of males	No. of females
Casual		
Permanent		
Village labour exchange		

ii) Second season

Type of hired labour	No. of males	No. of females
Casual		
Permanent		
Village labour exchange		

6. (e) For which activities do you use hired labour? (tick for the different types of hired labour)

Activity	Casual labour	Permanent labour	Village labour exchange
Land preparation			
Planting			
Weeding			
Harvesting			
On-farm transport			
Post-harvest processing			

C: Groundnut production

7 (a). Give constraints/problems affecting your g/nut production(tick which ever is appropriate and mention the copping strategy/mechanism

Constraint	Tick as appropriate	Copping strategy
Diseases (specify)		
Field Pests (specify)		
Shortage of land		
Land Opening		

Shortage of labour		
Drought		
Lack of quality seed		
Storage pests		
Low output prices		
Low/reduced soil fertility		
Others (specify)		

7. (b) Give acreage under improved and unimproved g/nut varieties:

Groundnuts	**Acreage**
Improved varieties	
Local varieties	

7. (c) Which varieties of ground nuts do you grow? (Tick appropriate)

Variety	**Year 1st planted**	**Initial source of seed**	**Current source of seed**
Igola 1 (India)			
Ebaya (Rebel)			
Emoita			
Erudurudu (red seeded)			
Erudurudu (light tan seeded)			
Etesoti			
Serenut 1			
Serenut 2			
Other (specify)			

7. (d) Why do you prefer these varieties grown? (see codes below)

Variety	**Reasons**
Igola 1 (India)	
Ebaya (Rebel)	
Emoita	
Erudurudu (red seeded)	
Erudurudu (light tan seeded)	
Etesoti	
Serenut 1	
Serenut 2	
Other (specify)	

Codes: *1= high yield; 2=disease resistance; 3=early maturity; 4=good taste; 5=good color; 6=drought resistance; 7=easy to pound, 8=good storeability; 9=weed suppression; 10=field pest resistance; 11=uniform maturity, 12=big seed; 13=ready market; 14=fetches higher prices*

7. (e) What don't you like about these varieties? (see codes below)

Variety	**Weaknesses/shortcomings**
Igola 1 (India)	

Ebaya (Rebel)	
Emoita	
Erudurudu (red seeded)	
Erudurudu (light tan seeded)	
Etesoti	
Serenut 1	
Serenut 2	
Other (specify)	

Codes: *1= poor yield; 2=susceptible to g/nut rossette disease; 3=late maturity; 4=bitter; 6= inferior drought tolerance; 7=hard to pound, 8=easily affected by storage pests; 9=difficult to harvest(requires digging up); 10=inferior taste (paste); 11=non uniform maturity, 12=small seed; 13=restricted marketability;*

8. Desirable characteristics of a good groundnut variety (in order of preference)

List desired characteristics, in order of importance

9. Which varieties would demand more labour and please explain why

10. Which colour of groundnuts do you prefer and give reasons for your preference
    i. Red
    ii. Light tan
    iii. No preference
    iv. Other (specify)

11. Groundnut Production System

Activity	Month(s)	Who performs?		
		Men	Women	Children
Field selection				
Bush clearing				
Ploughing				
Planting				
Weeding				
Harvesting				
Transportation (field-home)				
Drying				
Shelling/pod opening				
Sorting				
Storage				
Marketing				

12. Perceptions of Groundnut Rosette Disease (use photos)

12.(a)Do you know of Rosette Disease? Yes / No.

12. (b) What name do you call this Disease?

12. (c) What do you think causes this Disease?

12. (d) In your view how is the disease transmitted ?

12. (e) How do you try to control the rosette disease?

12. (f) What is the loss in yield due to rosette Disease?
  i. Low (Less than 20%)
  ii. Moderate (20-40%)
  iii. High (over 50%)
  iv. Total loss

12. (g). Do you know any variety(s), which is not affected by the rosette disease? Yes / No
Specify the variety(s)

12. (h) In your view what is the trend of occurrence of this disease over the years
  i. Increasing
  ii. Same
  iii. Decreasing

13. Perceptions of Groundnut Leaf miner (use photos brought out by F.Kimmins)

13.(a)Do you know of groundnut leaf miner? Yes / No.

13. (b) What name do you call the symptoms ?

13. (c) What do you think causes these symptoms?

13. (d) How do you try to control the symptoms?

13. (f) What is the loss in yield due to the symptoms?
  v. Low (Less than 20%)
  vi. Moderate (20-40%)
  vii. High (over 50%)
  viii. Total loss

13. (g). Do you know any variety(s), which is not affected? Yes / No
Specify the variety(s)

13. (h) In your view has the damage over the years
  iv. Increased
  v. Same
  vi. Decreased

14. . Do you plant your g/nuts in lines/rows? Yes / No (Specify spacing used)

15. . Do you grow g/nuts in pure stands
  i. Pure stands/sole crop
  ii. Mixed/intercropped

16. (a) How many times do you weed your groundnuts

i. Once
ii. Twice
iii. Thrice

16. (b) At what stage do you weed the groundnuts (specify)

17. What purchased inputs do you use in production of g/nuts

Input	Purchased, Borrowed or Hired	Approximate Cost

How easy is it for you to obtain the relevant inputs for production? (Use code below).

Type of input	**Input availability**			
Seeds				
Hoes				
Fertilizers				
Herbicides				
Insecticides				
Fungicides				
Others (specify)				

Code: 1=very easy; 2=easy; 3=not easy; 4=other (specify)

18. Use, Marketing and Decision Making

What are the uses of groundnuts	
What proportion do you sell?	
What proportion do you eat?	
What proportion do you retain for seed?	
If sold, where do you sell?	
If sold, when do you sell?	
If sold, shelled or unshelled?	
If sold, do you sell all at once?	
Do you store any of these groundnuts? If so where?	

18. (b) Who makes the following decisions?

Decision	Who makes?
How much to plant	
How much seed to retain	
How much to eat	
How much to sell	
When to sell	
Where to sell	

D. INSTITUTIONS

19. (a) Is any member of the household a member of any group/association? yes / no
If yes, specify what kind of group: (name the group)

Extension contact group	farmer association	Other (specify)

19. (b) What are the major functions of the group/association?
19. (c) When did you/they become a member of the group/association? (give year) ………
19. (d) Why did you/they become a member of the group (any benefits)?
19. (e) Does the group/association address agricultural issues? Yes ………. No ……….
19. (f) If yes, enumerate the agricultural issues addressed

20. (a) What are your major sources of information about agricultural activities (tick)
i. Government extension staff
ii. NGO (specify)
iii. Radio
iv. Neighbour / friend
v. School
vi. Parents
vii. Training workshop
viii. On farm research/demonstration
ix. Exchange visit/field tours
x. Visiting researchers
xi. Newspaper/newsletter/pamphlet
xii. Others (specify)

21. (a) Do you have a radio in your household? Yes /No
21. (b) If yes do you listen to agricultural education programs? Yes ……… No ………. (Name the program)

21. (c) If Yes, is the coverage of the program satisfactory ? Yes _____1 No _____2

22. (a) Did extension agent visit you last year? Yes _____1 No _____2
22. (b) If Yes, what time of the year or during which operation?
Plowing __________1 No. of visit ____________
Planting __________2 No. of visit ____________
Weeding __________3 No. of visit ____________
Harvesting ________4 No. of visit ____________
23. Have you ever attended a field day or demonstration trial? Yes _____1 No _____2
24. Have you ever attended a farmer's training course? Yes _____1 No _____2

25. Please give any comment / suggestion relating to agriculture and the groundnut production in particular.

Appendix 2 – Determinants of total and cultivated areas

A: Determinants of total planted area (dependent variable)

Descriptive Statistics

	Mean	Std. Deviation	N
Total Area	8.5435	8.8202	207
AGE	42.0435	15.1630	207
Education (1-5)	2.3285	.9234	207

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.281[a]	.079	.070	8.5074

a. Predictors: (Constant), Education (1-5), AGE

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1261.421	2	630.710	8.714	.000[a]
	Residual	14764.688	204	72.376		
	Total	16026.109	206			

a. Predictors: (Constant), Education (1-5), AGE

b. Dependent Variable: Total Area

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-1.173	2.419		-.485	.628	-5.943	3.597
	AGE	.112	.039	.193	2.859	.005	.035	.190
	Education (1-5)	2.144	.645	.224	3.322	.001	.872	3.417

a. Dependent Variable: Total Area

All confidence intervals calculated at 95% level.
Age = age of household head
Education = general level of education (where 1=illiterate and 5=college level or equivalent, with all stages in between)

B: Determinants of total cultivated area

Descriptive Statistics

	Mean	Std. Deviation	N
Cultivated Area	4.7947	3.6287	207
AGE	42.0435	15.1630	207
Education (1-5)	2.3285	.9234	207

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.249[a]	.062	.053	3.5318

a. Predictors: (Constant), Education (1-5), AGE

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	167.879	2	83.939	6.729	.001[a]
	Residual	2544.645	204	12.474		
	Total	2712.524	206			

a. Predictors: (Constant), Education (1-5), AGE

b. Dependent Variable: Cultivated Area

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.230	1.004		1.225	.222	-.750	3.211
	AGE	4.867E-02	.016	.203	2.983	.003	.017	.081
	Education (1-5)	.652	.268	.166	2.433	.016	.124	1.180

a. Dependent Variable: Cultivated Area

All confidence intervals calculated at 95% level.
Age = age of household head
Education = general level of education (where 1=illiterate and 5=college level or equivalent, with all stages in between)

Appendix 3 – Determinants of participation in non-farm activities

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	253.145	.042	.059

Classification Table[a]

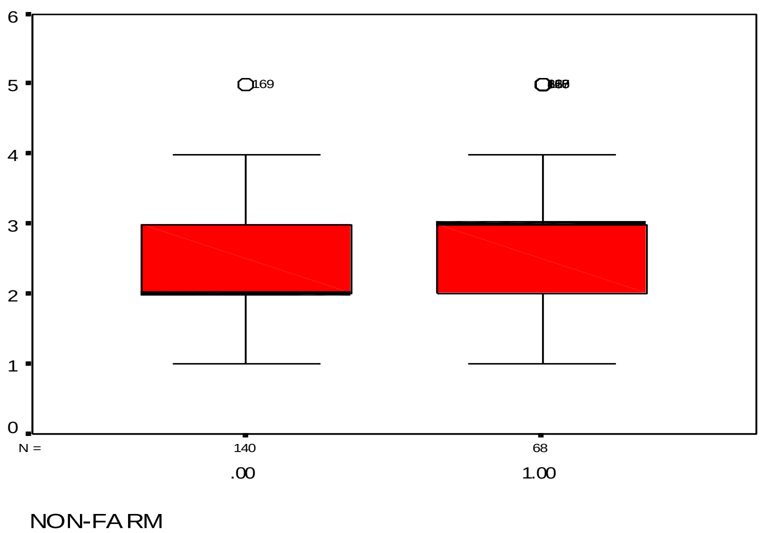
			Predicted		
			NON-FARM		Percentage Correct
	Observed		.00	1.00	
Step 1	NON-FARM	.00	137	2	98.6
		1.00	58	10	14.7
	Overall Percentage				71.0

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	AGE	.010	.010	.975	1	.323	1.010
	EDUCATIO	.476	.167	8.110	1	.004	1.609
	Constant	-2.275	.651	12.210	1	.000	.103

a. Variable(s) entered on step 1: AGE, EDUCATIO.



All analyses relate to presence (1) or non presence (0) of non-farm income in the household.

Appendix 4 – Determinants of participation in formal employment and trading/small business activity

A: Involvement in Formal Employment

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	168.872	.103	.170

Classification Table[a]

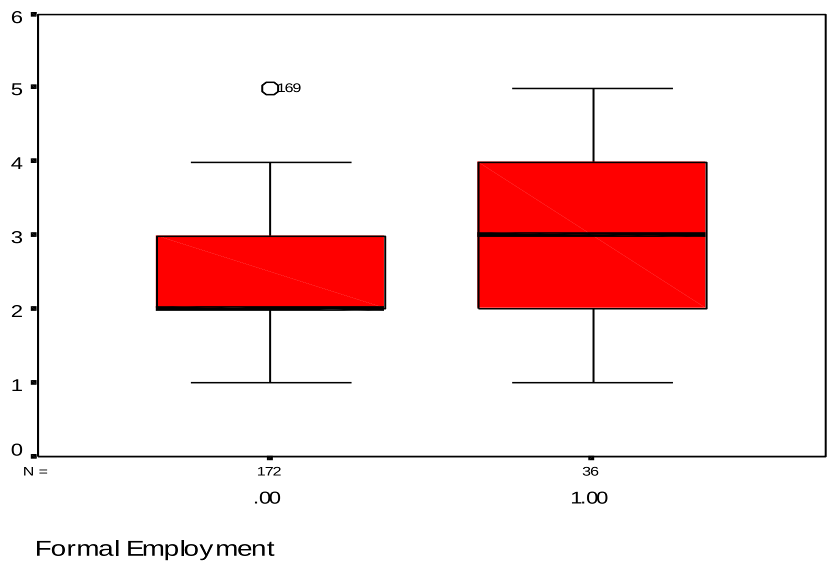
Observed			Predicted		
			Formal Employment		Percentage Correct
			.00	1.00	
Step 1	Formal Employment	.00	169	2	98.8
		1.00	30	6	16.7
	Overall Percentage				84.5

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	AGE	.031	.014	5.418	1	.020	1.032
	EDUCATIO	.887	.214	17.149	1	.000	2.428
	Constant	-5.180	.960	29.143	1	.000	.006

a. Variable(s) entered on step 1: AGE, EDUCATIO.



B: Involvement in Trading/Small Business Activity

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	185.331	.028	.047

Classification Table[a]

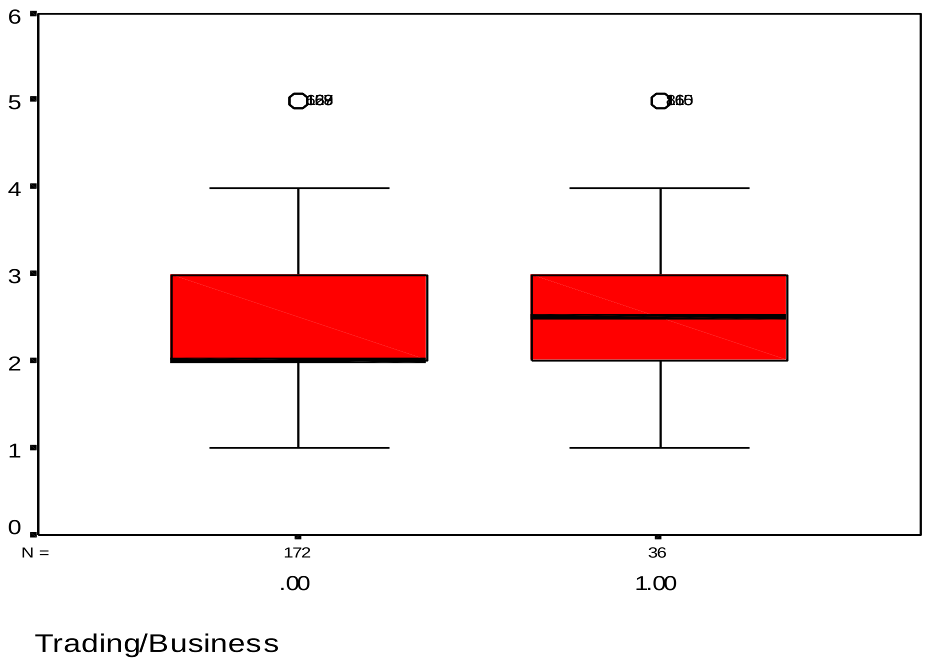
Observed			Predicted: Trading/Business .00	Predicted: Trading/Business 1.00	Percentage Correct
Step 1	Trading/Business	.00	171	0	100.0
		1.00	36	0	.0
	Overall Percentage				82.6

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	AGE	-.014	.013	1.172	1	.279	.986
	EDUCATIO	.405	.193	4.395	1	.036	1.499
	Constant	-1.959	.760	6.645	1	.010	.141

a. Variable(s) entered on step 1: AGE, EDUCATIO.



Appendix 5 – Determinants of total income sources

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.283[a]	.080	.062	.6353

a. Predictors: (Constant), Female Headed, AGE, SOROTI, Education (1-5)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.071	4	1.768	4.380	.002[a]
	Residual	81.519	202	.404		
	Total	88.589	206			

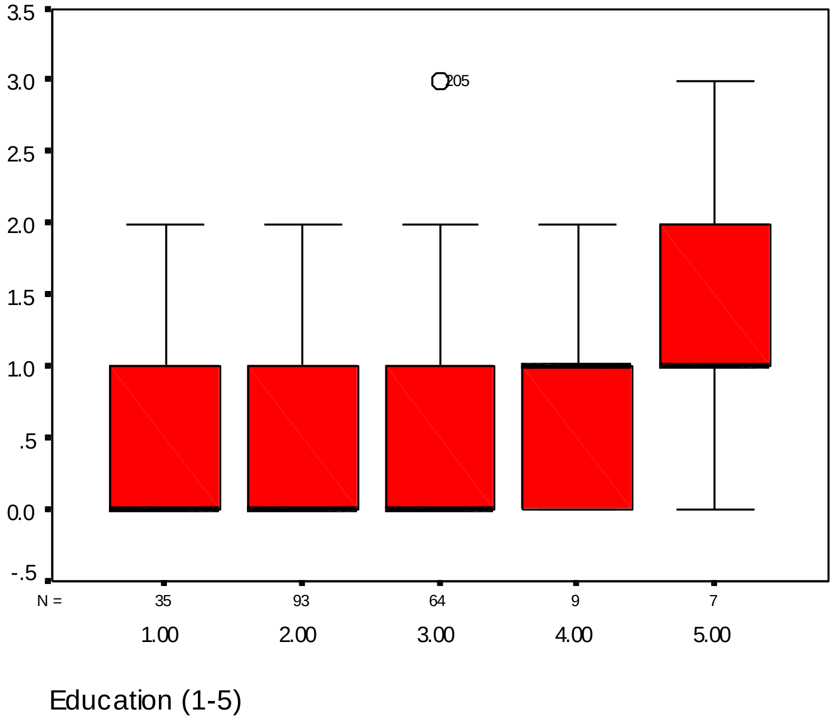
a. Predictors: (Constant), Female Headed, AGE, SOROTI, Education (1-5)

b. Dependent Variable: Total Income Sources (NF)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-.241	.199		-1.211	.227	-.633	.151
	AGE	3.176E-03	.003	.073	1.070	.286	-.003	.009
	Education (1-5)	.205	.051	.289	4.052	.000	.105	.305
	SOROTI	7.811E-02	.094	.057	.834	.405	-.107	.263
	Female Headed	.178	.132	.097	1.349	.179	-.082	.438

a. Dependent Variable: Total Income Sources (NF)


3.5
3.0
2.5
2.0
1.5
1.0
.5
0.0
-.5
205
N =
35
93
64
9
7
1.00
2.00
3.00
4.00
5.00
Education (1-5)

Appendix 6 – Determinants of differences between total and cultivated areas

Descriptive Statistics

	Mean	Std. Deviation	N
Area Difference	3.7404	6.5892	208
C:Labour Shortage	.6635	.4737	208
C:Soil Fertility	.5529	.4984	208
C:Output Prices	.5240	.5006	208

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.170[a]	.029	.015	6.5408

a. Predictors: (Constant), C:Output Prices, C:Labour Shortage, C:Soil Fertility

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	259.876	3	86.625	2.025	.112[a]
	Residual	8727.605	204	42.782		
	Total	8987.481	207			

a. Predictors: (Constant), C:Output Prices, C:Labour Shortage, C:Soil Fertility

b. Dependent Variable: Area Difference

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.473	.890		2.779	.006	.719	4.228
	C:Labour Shortage	1.852	.997	.133	1.857	.065	-.115	3.818
	C:Soil Fertility	1.267	1.020	.096	1.242	.216	-.744	3.278
	C:Output Prices	-1.263	1.010	-.096	-1.250	.213	-3.254	.728

a. Dependent Variable: Area Difference

Appendix 7 – Determinants of the uptake of improved groundnut varieties – influence of education

A: Influence of Illiteracy and Very High Education Levels

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	276.592	.032	.043

Classification Table[a]

Observed			Predicted: Presence of Improved Variety .00	Predicted: Presence of Improved Variety 1.00	Predicted: Percentage Correct
Step 1	Presence of Improved Variety	.00	21	67	23.9
		1.00	14	106	88.3
	Overall Percentage				61.1

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	ILLITERA	-.806	.382	4.459	1	.035	.447
	V12	.698	.600	1.356	1	.244	2.011
	Constant	.400	.163	6.040	1	.014	1.492

a. Variable(s) entered on step 1: ILLITERA, V12.

B: Influence of Education Levels (All from Illiteracy to High)

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	274.868	.040	.054

Classification Table[a]

Observed			Predicted: Presence of Improved Variety .00	Predicted: Presence of Improved Variety 1.00	Percentage Correct
Step 1	Presence of Improved Variety	.00	21	67	23.9
		1.00	14	106	88.3
	Overall Percentage				61.1

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	EDUCATIO	.470	.168	7.848	1	.005	1.600
	Constant	-.766	.404	3.599	1	.058	.465

a. Variable(s) entered on step 1: EDUCATIO.

C: Influence of Education (Primary and up)

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	275.799	.036	.048

Classification Table[a]

Observed			Predicted: Presence of Improved Variety .00	Predicted: Presence of Improved Variety 1.00	Percentage Correct
Step 1	Presence of Improved Variety	.00	21	67	23.9
		1.00	14	106	88.3
	Overall Percentage				61.1

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	V10	.687	.404	2.896	1	.089	1.987
	SECONDAR	.984	.432	5.175	1	.023	2.674
	V12	1.504	.673	5.001	1	.025	4.500
	Constant	-.405	.345	1.381	1	.240	.667

a. Variable(s) entered on step 1: V10, SECONDAR, V12.

Appendix 8 – Determinant of uptake of new varieties - information sources

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	270.888	.054	.072

Classification Table[a]

Observed			Predicted: Presence of Improved Variety .00	Predicted: Presence of Improved Variety 1.00	Predicted: Percentage Correct
Step 1	Presence of Improved Variety	.00	34	54	38.6
		1.00	26	93	78.2
	Overall Percentage				61.4

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	V49	-.155	.324	.230	1	.632	.856
	V50	.229	.459	.249	1	.618	1.258
	V51	.509	.323	2.492	1	.114	1.664
	V52	.320	.353	.824	1	.364	1.377
	V53	-.372	.410	.822	1	.365	.690
	V54	.087	.331	.069	1	.792	1.091
	V55	.100	.510	.038	1	.845	1.105
	V56	.784	.542	2.094	1	.148	2.190
	V57	-.524	.527	.988	1	.320	.592
	V58	-.070	.440	.026	1	.873	.932
	V59	.376	.376	1.003	1	.317	1.457
	V60	.479	.882	.295	1	.587	1.615
	Constant	-.353	.381	.860	1	.354	.703

a. Variable(s) entered on step 1: V49, V50, V51, V52, V53, V54, V55, V56, V57, V58, V59,

Appendix 9 – Determinants of the uptake of improved varieties - combined educational and information source influences

A: Where education defined in general levels (Illiteracy to High)

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	265.993	.076	.102

Classification Table[a]

	Observed		Predicted: Presence of Improved Variety .00	Predicted: Presence of Improved Variety 1.00	Predicted: Percentage Correct
Step 1	Presence of Improved Variety	.00	40	48	45.5
		1.00	25	94	79.0
	Overall Percentage				64.7

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	V49	-.126	.328	.147	1	.702	.882
	V50	.059	.477	.015	1	.902	1.060
	V51	.383	.332	1.332	1	.248	1.466
	V52	.338	.358	.889	1	.346	1.402
	V53	-.432	.421	1.053	1	.305	.649
	V54	.157	.337	.218	1	.641	1.170
	V55	.081	.522	.024	1	.877	1.084
	V56	.723	.553	1.710	1	.191	2.061
	V57	-.628	.537	1.368	1	.242	.534
	V58	-.032	.454	.005	1	.944	.969
	V59	.257	.385	.447	1	.504	1.293
	V60	.661	.895	.544	1	.461	1.936
	EDUCATIO	.403	.187	4.639	1	.031	1.496
	Constant	-1.155	.538	4.618	1	.032	.315

a. Variable(s) entered on step 1: V49, V50, V51, V52, V53, V54, V55, V56, V57, V58, V59, V EDUCATIO.

B: Where education defined as illiteracy and high

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	266.360	.074	.100

Classification Table[a]

Observed			Predicted		
			Presence of Improved Variety		Percentage Correct
			.00	1.00	
Step 1	Presence of Improved Variety	.00	33	55	37.5
		1.00	24	95	79.8
	Overall Percentage				61.8

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	V49	-.158	.329	.232	1	.630	.854
	V50	.175	.468	.139	1	.709	1.191
	V51	.423	.333	1.620	1	.203	1.527
	V52	.360	.360	.999	1	.317	1.433
	V53	-.449	.423	1.126	1	.289	.638
	V54	.126	.337	.140	1	.708	1.135
	V55	.081	.522	.024	1	.877	1.084
	V56	.809	.557	2.111	1	.146	2.246
	V57	-.683	.541	1.594	1	.207	.505
	V58	-.022	.457	.002	1	.961	.978
	V59	.198	.389	.258	1	.611	1.218
	V60	.751	.910	.681	1	.409	2.119
	ILLITERA	-.680	.431	2.495	1	.114	.506
	V12	.775	.648	1.429	1	.232	2.170
	Constant	-.192	.405	.224	1	.636	.825

a. Variable(s) entered on step 1: V49, V50, V51, V52, V53, V54, V55, V56, V57, V58, V59, ILLITERA, V12.

C: Where Education Defined as Primary through to High

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	266.295	.074	.100

Classification Table[a]

Observed			Predicted		
			Presence of Improved Variety		Percentage Correct
			.00	1.00	
Step 1	Presence of Improved Variety	.00	33	55	37.5
		1.00	24	95	79.8
	Overall Percentage				61.8

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	V49	-.153	.329	.217	1	.641	.858
	V50	.146	.482	.092	1	.761	1.158
	V51	.410	.337	1.477	1	.224	1.506
	V52	.358	.360	.991	1	.320	1.431
	V53	-.445	.424	1.101	1	.294	.641
	V54	.132	.338	.153	1	.696	1.141
	V55	.081	.523	.024	1	.877	1.084
	V56	.788	.563	1.960	1	.162	2.198
	V57	-.673	.543	1.535	1	.215	.510
	V58	-.025	.457	.003	1	.956	.975
	V59	.208	.391	.282	1	.596	1.231
	V60	.750	.910	.678	1	.410	2.116
	V12	1.460	.744	3.847	1	.050	4.306
	V10	.649	.448	2.104	1	.147	1.914
	SECONDAR	.743	.495	2.250	1	.134	2.101
	Constant	-.869	.498	3.045	1	.081	.419

a. Variable(s) entered on step 1: V49, V50, V51, V52, V53, V54, V55, V56, V57, V58, V59, V6
V12, V10, SECONDAR.

Appendix 10 – Determinants of total number of information sources

Descriptive Statistics

	Mean	Std. Deviation	N
Total No. Sources	3.6250	2.3248	208
Cultivated Area	4.7861	3.6221	208

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.251[a]	.063	.059	2.2555

a. Predictors: (Constant), Cultivated Area

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	70.743	1	70.743	13.905	.000[a]
	Residual	1048.007	206	5.087		
	Total	1118.750	207			

a. Predictors: (Constant), Cultivated Area

b. Dependent Variable: Total No. Sources

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.853	.260		10.990	.000	2.341	3.364
	Cultivated Area	.161	.043	.251	3.729	.000	.076	.247

a. Dependent Variable: Total No. Sources

Appendix 11 – Market integration and colour preferences

A: Red Seeded Preference

Descriptive Statistics

	Mean	Std. Deviation	N
Proportion Sold	32.3894%	29.6571%	208
Red Preference	.4663	.5001	208

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.091[a]	.008	.003	29.6058%

a. Predictors: (Constant), Red Preference

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1506.192	1	1506.192	1.718	.191[a]
	Residual	180559.3	206	876.501		
	Total	182065.5	207			

a. Predictors: (Constant), Red Preference

b. Dependent Variable: Proportion Sold

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	29.874	2.810		10.631	.000	24.334	35.414
	Red Preference	5.394	4.115	.091	1.311	.191	-2.719	13.507

a. Dependent Variable: Proportion Sold

B: Tan Seeded Preference

Descriptive Statistics

	Mean	Std. Deviation	N
Proportion Sold	32.0628%	29.3516%	207
Tan Preference	.2367	.4261	207

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.115[a]	.013	.008	29.2268%

a. Predictors: (Constant), Tan Preference

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2359.696	1	2359.696	2.762	.098[a]
	Residual	175112.5	205	854.207		
	Total	177472.2	206			

a. Predictors: (Constant), Tan Preference

b. Dependent Variable: Proportion Sold

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	33.943	2.325		14.598	.000	29.359	38.527
	Tan Preference	-7.943	4.779	-.115	-1.662	.098	-17.365	1.479

a. Dependent Variable: Proportion Sold

C: No Colour Preference

Descriptive Statistics

	Mean	Std. Deviation	N
Proportion Sold	32.3894%	29.6571%	208
No Preference	.2981	.4585	208

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.012[a]	.000	-.005	29.7268%

a. Predictors: (Constant), No Preference

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26.338	1	26.338	.030	.863[a]
	Residual	182039.1	206	883.685		
	Total	182065.5	207			

a. Predictors: (Constant), No Preference

b. Dependent Variable: Proportion Sold

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	32.158	2.460		13.071	.000	27.307	37.008
	No Preference	.778	4.506	.012	.173	.863	-8.106	9.662

a. Dependent Variable: Proportion Sold

Appendix 12 – Determinants of access to extension advice

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	279.975	.025	.033

Classification Table[a]

			Predicted		
			I:Extension Staff		Percentage Correct
	Observed		.00	1.00	
Step 1	I:Extension Staff	.00	76	32	70.4
		1.00	56	42	42.9
	Overall Percentage				57.3

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	AGE	.021	.009	4.983	1	.026	1.021
	Constant	-.987	.423	5.450	1	.020	.373

a. Variable(s) entered on step 1: AGE.

Appendix 13 – Determinants of access to NGO (agricultural) advice

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	174.915	.091	.150

Classification Table[a]

Observed			Predicted I:NGO .00	Predicted I:NGO 1.00	Predicted Percentage Correct
Step 1	I:NGO	.00	166	5	97.1
		1.00	33	4	10.8
	Overall Percentage				81.7

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	EDUCATIO	.748	.205	13.376	1	.000	2.113
	CULTIVAT	.091	.046	3.895	1	.048	1.095
	Constant	-3.897	.630	38.295	1	.000	.020

a. Variable(s) entered on step 1: EDUCATIO, CULTIVAT.

Appendix 14 – Determinants of access to radio transmitted agricultural advice

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	242.591	.119	.163

Classification Table[a]

Observed			Predicted I:RADIO .00	Predicted I:RADIO 1.00	Predicted Percentage Correct
Step 1	I:RADIO	.00	27	46	37.0
		1.00	12	122	91.0
	Overall Percentage				72.0

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	EDUCATIO	.482	.199	5.853	1	.016	1.620
	CULTIVAT	.126	.056	5.076	1	.024	1.135
	AGE	-.018	.010	2.902	1	.088	.982
	V6	.908	.440	4.247	1	.039	2.478
	Constant	-1.052	.672	2.446	1	.118	.349

a. Variable(s) entered on step 1: EDUCATIO, CULTIVAT, AGE, V6.

Appendix 15 – Determinants of access to newspaper based agricultural advice

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	236.265	.114	.159

Classification Table[a]

Observed			Predicted I:Newspaper .00	Predicted I:Newspaper 1.00	Predicted Percentage Correct
Step 1	I:Newspaper	.00	130	11	92.2
		1.00	50	17	25.4
	Overall Percentage				70.7

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	EDUCATIO	.774	.185	17.405	1	.000	2.168
	CULTIVAT	.070	.042	2.790	1	.095	1.073
	Constant	-2.965	.518	32.726	1	.000	.052

a. Variable(s) entered on step 1: EDUCATIO, CULTIVAT.

Appendix 16 – Programme for the workshop held on 24-25th February 2000

Programme

Day one

Kimmins, F.M.	Introduction to the DFID CPP groundnut project and workshop.
Overfield, D and Kayobyo, G.	Groundnut in the Teso system and planned activities.
Kimmins F.M., van der Merwe P. and Naidu R.A.	Groundnut rosette virus disease: a constraint to groundnut production in sub-Saharan Africa
van der Merwe, P	ICRISAT's breeding programme.
Busolo- Bulafo, C.	Breeding and new releases in Uganda.
Mangheni W.O	The Uganda Seed Project and groundnut seed production in Uganda.
Obukui, R.	*A farmer's perspectives of groundnut production in the Teso system. No written submission.*
Adupa, R.	Seed multiplication at the community and farm level: the AT (Uganda) Experience.
Opoi, M.	Seed multiplication at the community and farm level: Socadido.
Aben, C and Ekiyar V	Seed multiplication at the community and farm level: Extension services.
Jefferies, D.	On farm seed selection and trials:a biometrician's perspective.

Day two

Two working groups to discuss how projects could address the needs of groundnut farmers in the Teso System, implementing agencies and researchers.

Presentations from two groups and discussion

Round-up of workshop and production of recommendations

Selection of papers to be produced in proceedings

Appendix 17 – List of participants at the workshop held 24 – 25th February 2000

Appendix 18 – Programme for the workshop held on 13th March 2002

Programme

a.m.

Welcome: Dr Charles Busolo-Bulafu, Head of the Oil Seeds Programme, SAARI.
Opening address: Dr L. Serunjogi, Director of SAARI.

1. Department for International Development, Crop Protection Programme. Dr Frances Kimmins. Deputy Manager, CPP.
2. The socio-economic context of groundnut production in eastern Uganda. Dr Duncan Overfield, Dr Tim Chancellor and Bill Page. Presented by Dr Tim Chancellor, NRI, Leader of the Groundnut Rosette Management Project.
3. Status of the groundnut leaf miner (Aproaerema modicella) in Uganda. Dr George Epieru, Entomologist, SAARI.
4. Evaluation of short duration groundnut varieties for rosette resistance in Uganda. Dr Charles M. Busolo-Bulafu and Pascal W. Nalyongo, Oil Seeds Programme, SAARI.
5. Seed-borne virus diseases: a potential threat to groundnut crop improvement in African countries. Dr R.A. Naidu, Virologist, Department of Plant Pathology, University of Georgia, USA.
6. Participatory on-farm trials of candidate resistant groundnut varieties. Dr Duncan Overfield, Bill Page, Dr Charles Busolo-Bulafu and David Jeffries. Presented by Bill Page, Consultant Entomologist.
7. Presentations on working with groundnut farmer groups:
(a) SOCADIDO. Florence Agoe
(b) DAO, Kumi. Valdo Odeke
(c) DAO, Katakwi. B. Silver Ongom
(d) AT (Uganda) Robert Adupa
8. Commercialisation of rosette resistant groundnut varieties: IDEA's approach. Dr Fred Muhhuku, IDEA

p.m.

9. A farmer's view of the on farm trials. Stanley Akol.

Discussion sessions:

Promotion of outputs

10. Farmer-led multiplication of rosette resistant varieties. Dr Rita Laker Ojok, AT (Uganda)

Training

11. Introduction of the groundnut manual. Bill Page.
12. Knowledge Transfer: The Scope for Further Knowledge dissemination through Farmer Field School and utility of the Groundnut production Manual. James Robert Okoth, IPPM - FFS Programme, Uganda.

Future research needs

Appendix 19 – List of participants at the workshop held on 13th March 2002

N°	Name	Organisation	Address	Contact
1	Dan Kisauzi	DFID - EA	Box 22130, Kampala	dfidnr@nida.or.ug
2	George Epieru	SAARI	P.O. Box Soroti	corsu@infocom.co.ug
3	Pascal Nalyongo	SAARI	P.O. Box Soroti	corsu@infocom.co.ug
4	Rayapati A. Naidu	University of West Georgia	Department of Plant Pathology, University of Georgia, USA	naidu@arches.uga.edu
5	Fred Muhhuku	ADC/IDEA		adc@starcom.co.ug
6	Nathon Nangoti	SAARI	P.O. Box Soroti	corsu@infocom.co.ug
7	Valdo Odeke	DAO, Kumi	Box 44, Kumi	077 463936
8	Frances Kimmins	NRInternational	Park House, Bradbourne Lane, Aylsford, Kent, ME20 6SN	F.Kimmins@nrint.co.uk
9	Tim Chancellor	NRI	Chatham Maritime, Chatham, Kent, ME4 4TB	t.c.b.chancellor@gre.ac.uk
10	Bill Page		6, Tinbridge Oast, Canterbury Road, Faversham, Kent ME13 9LJ	william@wpage78.freeserve.co.uk
11	B. Silver Ongom	DAO, Katakwi	Private Bag, Katakwi	045 73004
12	Charles Busolo-Bulafu	SAARI	P.O. Box Soroti	andyp@imul.com 077 488727
13	Stanley Akol		Kachaboi	
14	Robert Adupa	AT (Uganda)	Box 8830, Kampala	aduparobert@yahoo.com 077 586220
15	Dennis Ebinu	FEW	Kalaki/Karamaido	
16	James Okoth	FAO	Box 363, Soroti	ffsug@africaonline.co.ug 077 442773
17	Florence Agoe	SOCADIDO	Box 641, Soroti	077 557635
18	Lastus K. Serunjogi	Ag Director SAARI	P.O. Box Soroti	corsu@infocom.co.ug
19	Everlyne Atukoit	SAARI	P.O. Box Soroti	corsu@infocom.co.ug
20	Eric Manyasa	ICRISAT	Box 39063, Nairobi	E.Manyasa@cgiar.org
21	S. Sreenivasaprasad	HRI, UK	Wellesbourne, Warwicks, CI35 9EF	ss.prasad@hri.ac.uk
22	Prof Obilana	ICRISAT	Box 39063, Nairobi	a.obilana@cgiar.org
23	Dr B. Akello	SAARI	P.O. Box Soroti	corsu@infocom.co.ug
24	Rita Laker-Ojok	AT (Uganda)	Box 8830, Kampala	rojok@imul.com

Appendix 20: Yield performance (kg/ha dry pods) for 1st seasons 1999-2001 and 2nd season, 2001, at 6 locations

Table 1: Yield performance (kg/ha dry pods) rosette count for 1st season, 1999, at 6 locations

Variety	SAARI		Kumi		Kuju		Nakabango		Ngetta		Aduku		Mean	Mean
	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count
93530	2710	0.0	2568	0.0	3000	0.0	2280	0.0	3250	0.2	2380	0.0	2698	0
93535	2800	0.0	2453	0.0	2980	0.0	2100	0.0	2550	0.5	2500	0.0	2564	0
93524	2515	1.0	2410	1.0	2910	1.0	2000	1.0	2750	3.2	2250	0.0	2473	1.2
94581	1997	2.0	2050	1.0	2670	1.0	2215	1.0	1.750	0.6	2130	0.0	2135	1
99540	1860	10.7	1735	11.0	1950	9.0	1847	8.0	3400	0.0	2500	0.0.	2215	6.45
12991	2885	0.0	2570	0.0	2740	0.0	2335	1.0	3000	0.0	2130	0.0	2610	0.1
R. B	1790	30	1700	52	1953	57	1630	67.0	1750	53.0	1850	43.0	1779	50.3
94584	2857	1.0	2737	1.0	2875	2.0	2110	3.1	2100	0.0	2000	0.0	2447	1.2
93557	2334	2.0	2230	2.0	2346	2.0	2160	4.2	2000	1.0	2380	1.0	2242	2
Sere. II	2900	0.0	2800	0.0	3015	0.0	2310	0.0	2780	0.0	2380	0.0	2698	0

Table 2: Yield performance (kg/ha dry pods) for 1st season, 2000, at 6 locations

Variety	SAARI		Kumi		Kuju		Nakabango		Ngetta		Aduku		Mean	Mean
	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count
93530	2800	0.5	2525	0.0	2500	0.8	-	-	2375	0.0	3375	1.3	2262.5	0.43
93535	2600	0.2	1900	1.0	2475	3.2	-	-	2500	0.0	1250	1.5	1787.5	0.98
93524	2510	0.0	2125	0.75	2800	1.8	-	-	2250	0.0	2125	2.0	2018.3	0.758
94581	2010	0.2	2000	0.0	2400	0.8	-	-	2125	0.8	2200	1.8	1789.2	0.6
99540	1890	3.2	2475	6.7	2725	1.8	-	-	2500	2.0	2500	7.2	2015	3.483
12991	2803	0.2	2300	5.25	2825	3.7	-	-	2125	0.0	2530	0.8	2097.2	1.658
R. B	1690	25.0	1100	105.25	1325	71.0	-	-	1850	20.0	1350	166.8	1219.2	64.675
94584	2769	12.8	1800	0.0	2550	1.8	-	-	2000	0.0	1550	1.8	1778.2	2.73
93557	2400	0.5	1925	4.5	1950	1.8	-	-	2375	1.3	1250	2.2	1650	1.716
Sere. II	2880	0.0	2300	0.0	3200	1.0	-	-	2375	0.0	1750	1.0	1652	0.3

Table 3: Yield performance (kg/ha dry pods) for 2nd season, 2001, at 6 locations

Variety	SAARI		Kumi		Kuju		Nakabango		Ngetta		Aduku		Mean	Mean
	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count	Yield	Rosette Count
93530	2300	0.5	-	-	1900	0.9	2275	1.7	2735	1.5	-	-	1535	0.42
93535	1750	0.2	-	-	1450	3.0	2022	1.9	1255	1.7	-	-	1079.5	1.13
93524	2340	0.0	-	-	1800	1.9	1981	3.0	2130	2.1	-	-	1375	1.2
94581	2880	0.2	-	-	1400	0.9	2100	3.1	2205	1.9	-	-	1430.8	1.02
99540	3025	3.2	-	-	1730	3.0	2401	6.9	2505	7.3	-	-	1610.2	3.4
12991	2995	1.1	-	-	2000	3.5	2490	1.5	2405	1.0	-	-	1648.8	1.18
R.B	1125	29.0	-	-	1300	70.0	1200	62	1350	168.9	-	-	1658	54.98
94584	2300	13.0	-	-	1560	1.9	1460	2.0	1557	1.9	-	-	1146.2	3.1
93557	1730	0.7	-	-	1400	1.9	1320	3.1	1256	2.2	-	-	951	1.32
Sere. II	2998	0.0	-	-	2200	1.0	2550	1.6	1755	1.3	-	-	1583.8	0.65

Appendix 21 – Trial design and monitoring form

DATA MONITORING SHEET

Organisation:……………………… **Organiser:**……………………………

District:…………………………….. **County:**…………………. **Sub-County:**…………………………

Parish:…………………………………… **Village:**………………………………………………

Farm Number:…………… **Farmer name:**…………………… **Sex:**..…..

Owns oxen (tick): [Yes] [No] **Farm acreage (tick):** [3 or less] [more than 3,less than 8] [8 or more]

Detail of trial block (tick): [flat] [slope] [shaded] [low-lying] [sandy soil] [murram] other ………………………

- Variety number to plant in plots in the following order:

In PLOT No.	Plant VARIETY No.
1	(3 rows)
2	(3 rows)
3	(3 rows)
4	(3 rows)
5	(3 rows)
6	(3 rows)
7	(3 rows)

Varieties 1-6 are test varieties, Variety 7 is the farmer's own variety.

Name of farmer's variety: ………………………………….

- Each plot should be planted using the following dimensions:

All rows 45cm apart. 3 rows per variety, 50 plants per row, 10cm apart (planting 1 seed per stand) i.e.

```
x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x
x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x 1st var.
x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x..x
x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x
x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x 2nd var.
x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x_x
etc.
```

- Each variety should be planted adjacent to each other in one block. If this is not possible draw a map of layout on other side of this sheet. Also record if there is any unusual damage, loss of plants etc. on other side.

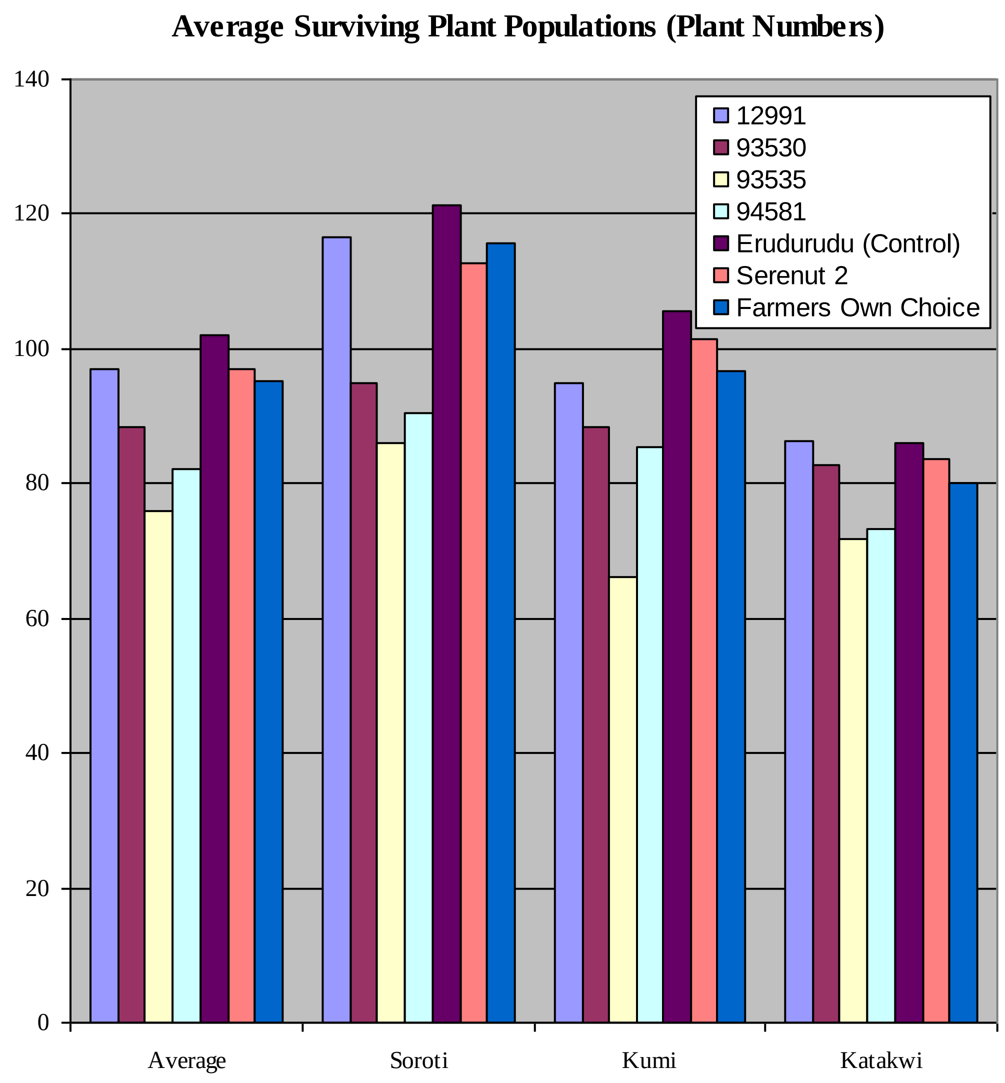
Date planted…………………………………….

	Days from planting to harvest	**Date harvested**	**No. plants**	**Leafspot ranking (1-7)***	**Rosette ranking (1-7)***	**Total wet weight unshelled (g)**	**Total dry weight unshelled (g)**	**Total dry weight shelled (g)**
Variety 1	105							
Variety 2	105							
Variety 3	105							
Variety 4	105							
Variety 5	120							
Variety 6	105							
Variety 7	105 or 120^+							

Note: record harvest data for variety number <u>not</u> for plot number.

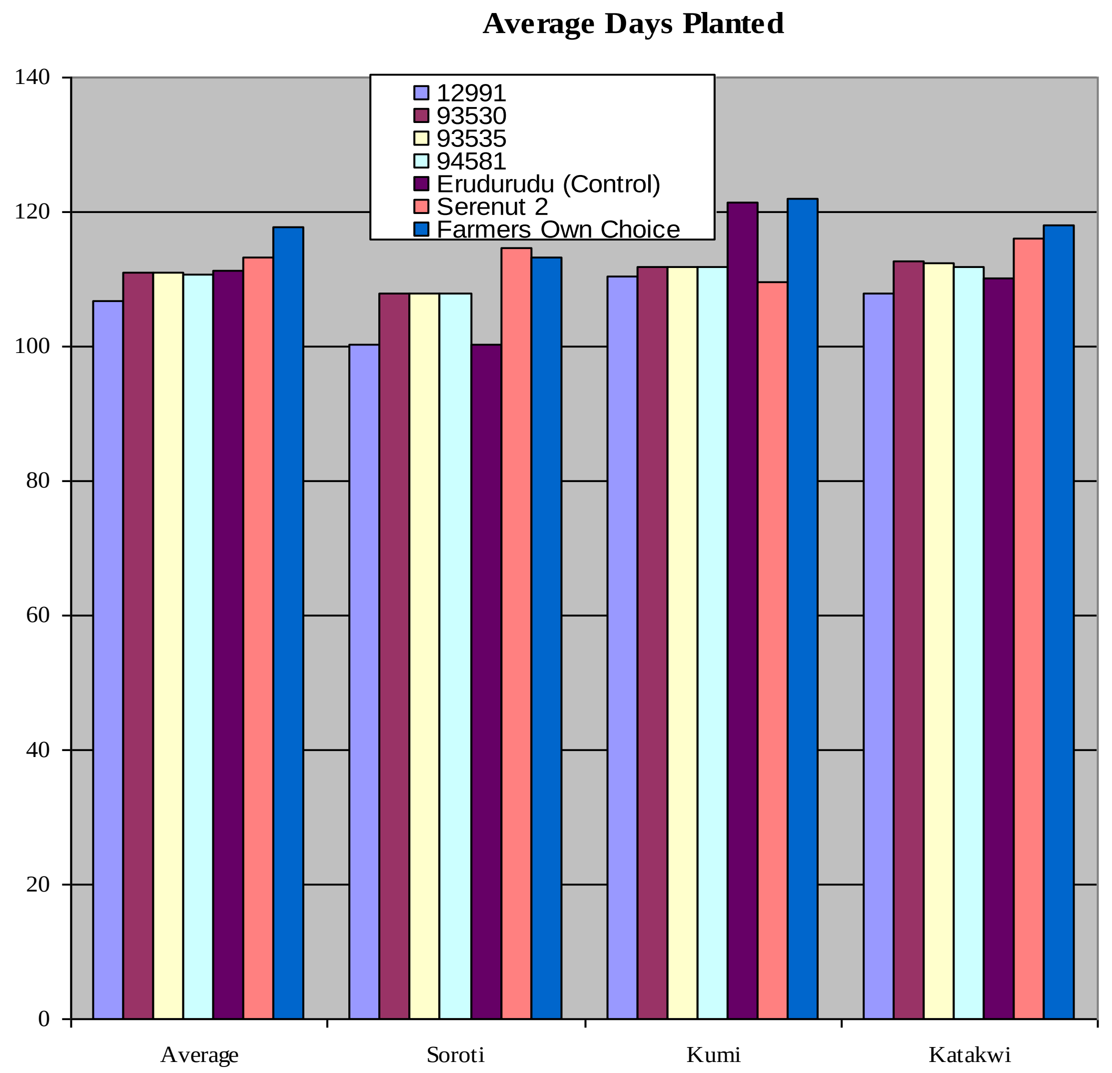
Appendix 22 – Average surviving plant populations

Surviving plant populations are out of 150 (3 rows at 50 each)



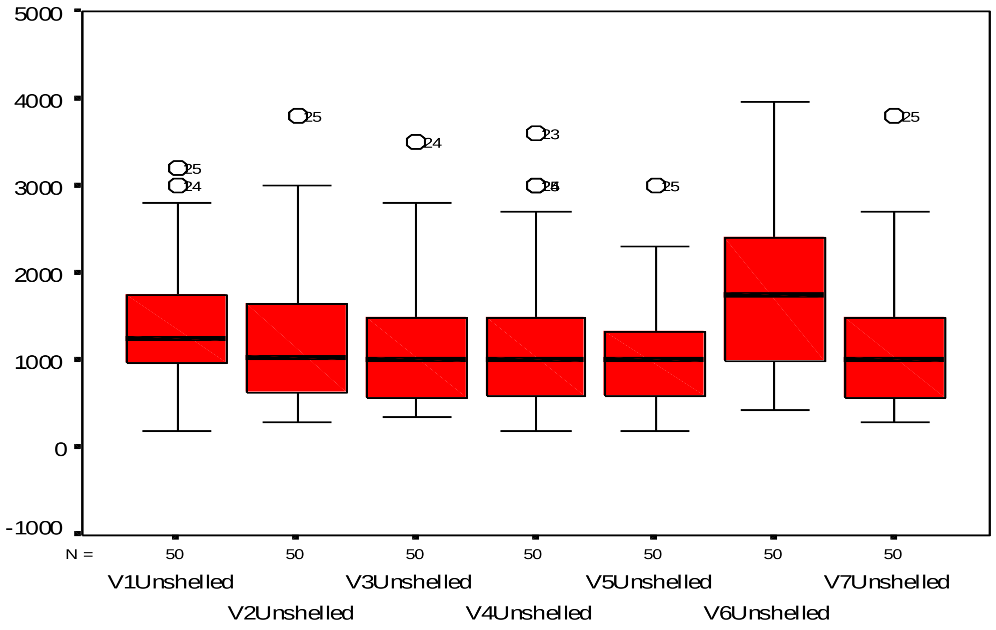
Variety	Mean (plant no.)	Standard Deviation	Confidence Interval (95%)
12991	98	24	91-106
93530	89	27	81-97
93535	77	29	69-86
94581	82	27	74-90
Erudurudu (Control)	102	30	93-111
Serenut 2	99	28	91-107
Farmers Own Choice	96	33	86-106

Appendix 23 – Average days planted



Variety	Mean (days)	Standard Deviation	Confidence Interval (95%)
12991	106	12	103-110
93530	111	9	108-113
93535	111	9	108-113
94581	111	11	108-113
Erudurudu (Control)	111	13	107-114
Serenut 2	113	12	110-117
Farmers Own Choice	118	12	114-121

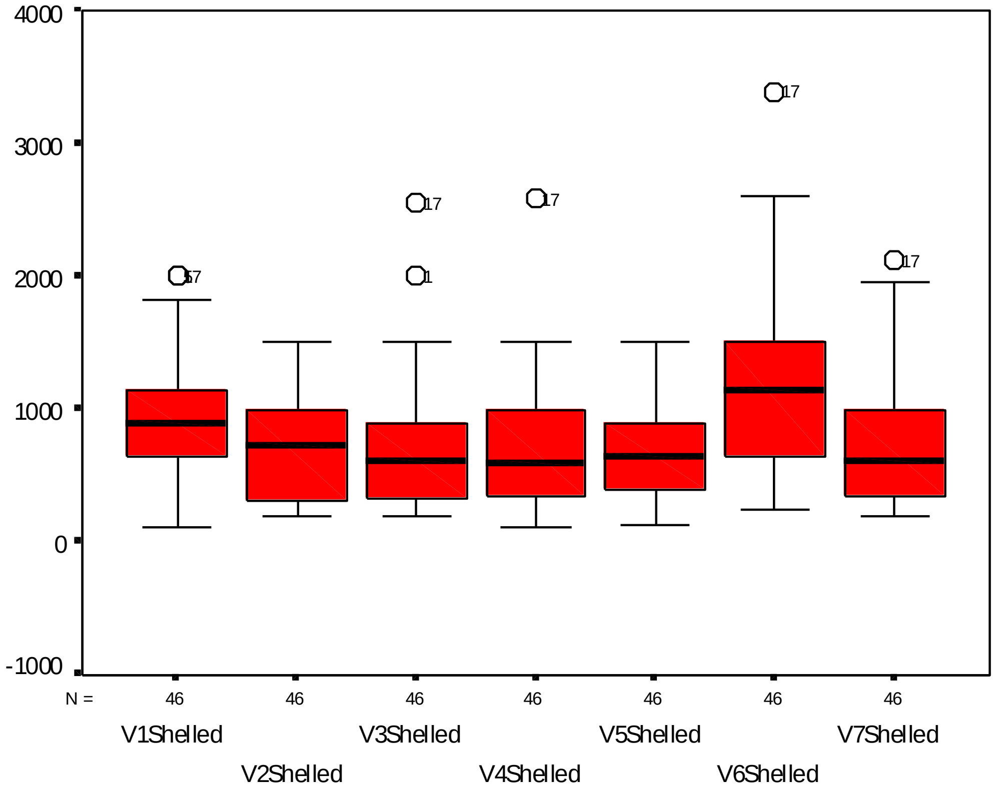
Appendix 24 – Unshelled yield statistics and box plots



Where V1=12991
V2=93530
V3=93535
V4=94581
V5=Erudurudu (Control)
V6=Serenut 2
V7=Farmers Own Choice

Variety	**Mean (g/plot)**	**Standard Deviation (g)**	**Confidence Interval (95%)**
12991	1414	729	1206-1620
93530	1254	745	1042-1466
93535	1175	717	971-1379
94581	1179	750	966-1392
Erudurudu (Control)	1056	567	894-1217
Serenut 2	1727	868	1480-1973
Farmers Own Choice	1189	744	978-1401

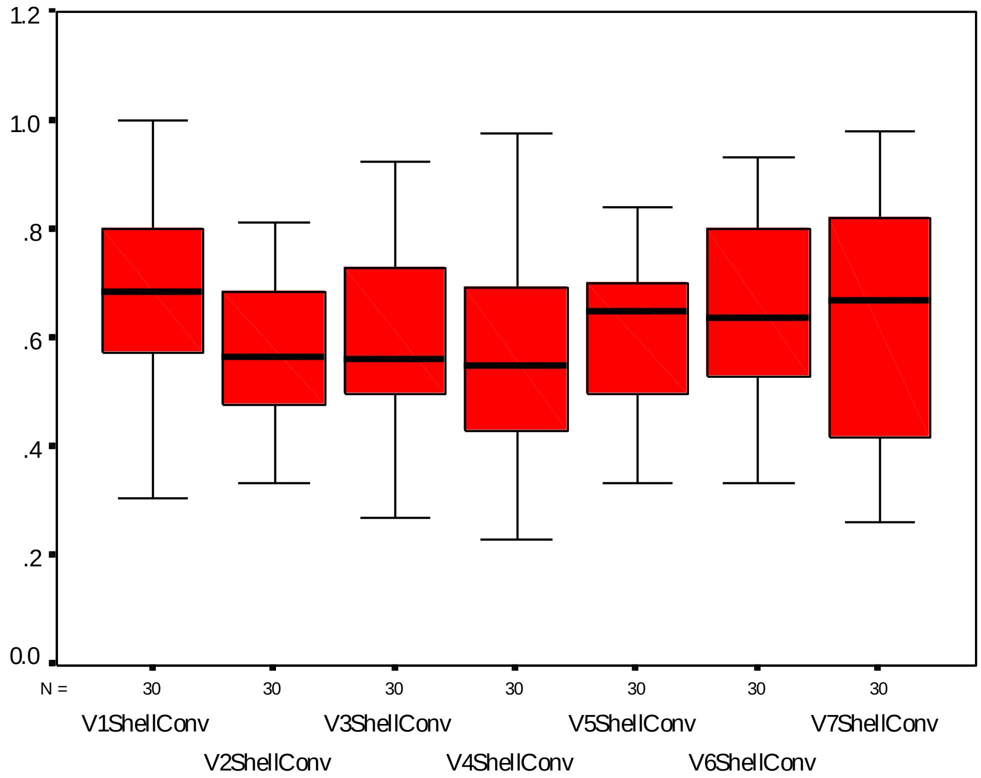
Appendix 25 - Shelled yield statistics and box plots



Where V1=12991
V2=93530
V3=93535
V4=94581
V5=Erudurudu (Control)
V6=Serenut 2
V7=Farmers Own Choice

Variety	**Mean (g/plot)**	**Standard Deviation (g)**	**Confidence Interval (95%)**
12991	927	454	792-1062
93530	701	359	595-808
93535	701	472	561-841
94581	699	467	560-838
Erudurudu (Control)	649	314	556-742
Serenut 2	1130	643	939-1320
Farmers Own Choice	753	485	609-897

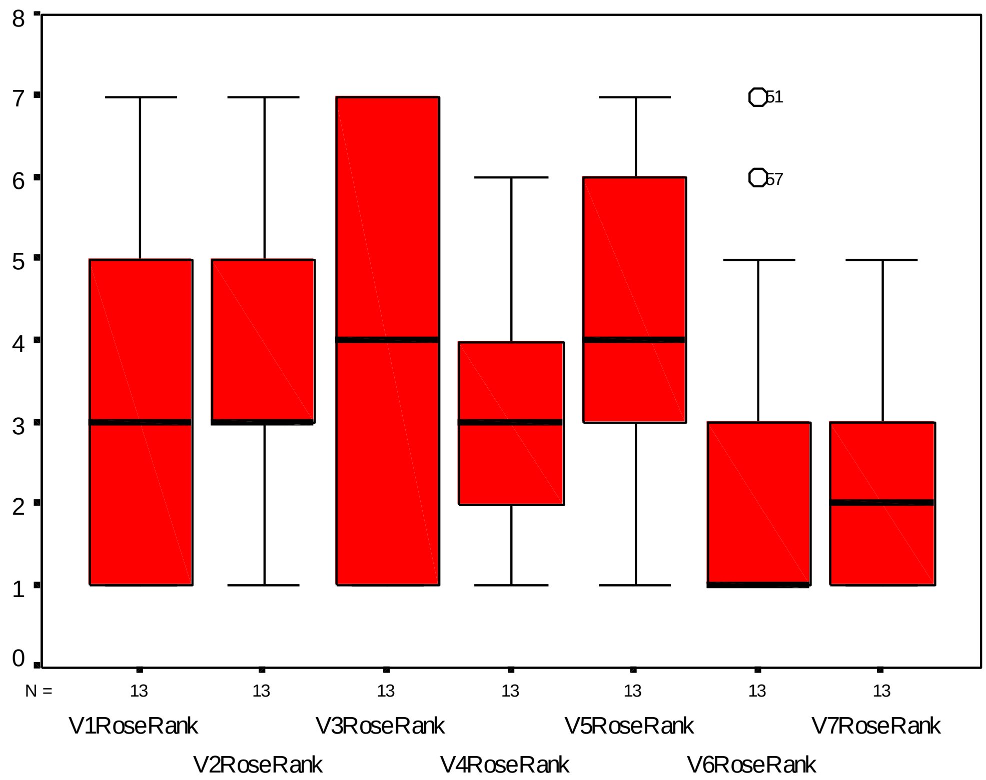
Appendix 26 – Shelling conversion ratios



Where V1=12991
V2=93530
V3=93535
V4=94581
V5=Erudurudu (Control)
V6=Serenut 2
V7=Farmers Own Choice

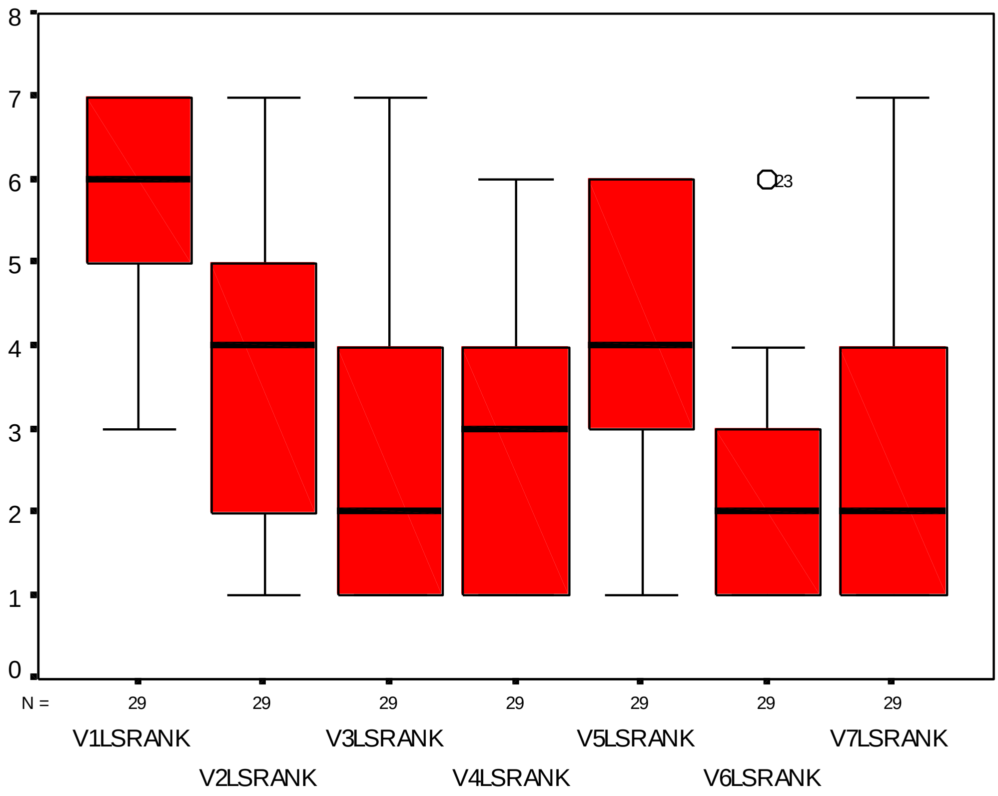
Variety	**Mean (ratio)**	**Standard Deviation**	**Confidence Interval (95%)**
12991	.665	.162	.601-.729
93530	.5703	.1426	.5170-.6236
93535	.587	.169	.524-.650
94581	.5808	.1827	.5126-.6490
Erudurudu (Control)	.6232	.1319	.5739-.6724
Serenut 2	.638	.176	.572-.704
Farmers Own Choice	.6145	.2031	.5386-.6903

Appendix 27 – Rosette and leaf spot rankings – statistics and box plots



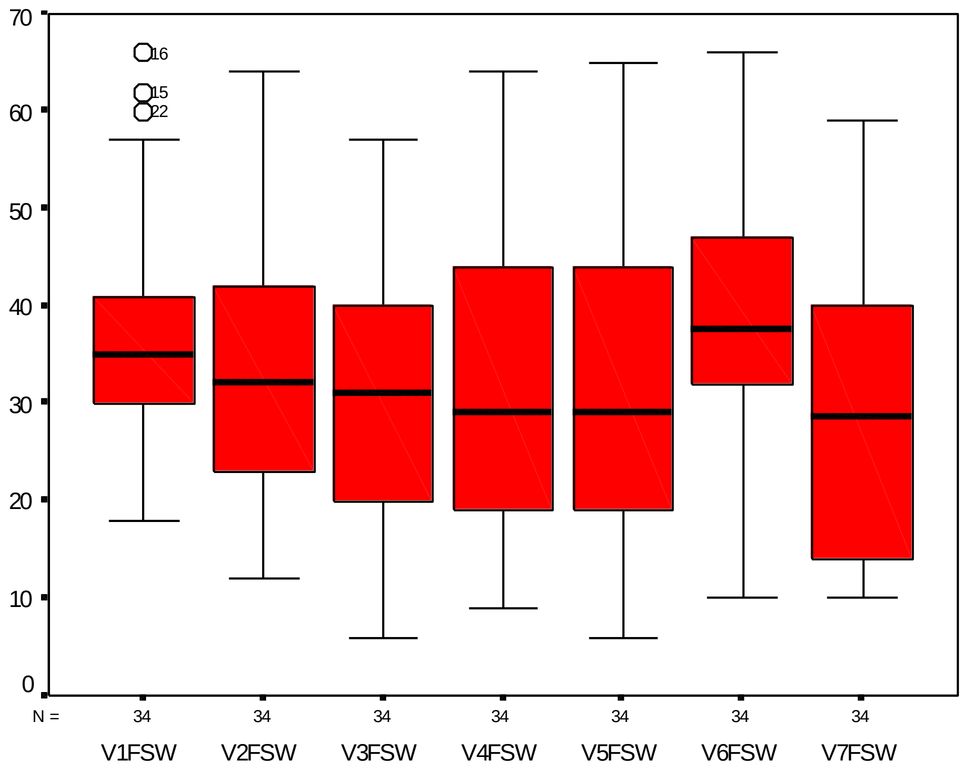
Where V1=12991
V2=93530
V3=93535
V4=94581
V5=Erudurudu (Control)
V6=Serenut 2
V7=Farmers Own Choice

Variety	Mean (rank)	Standard Deviation	Confidence Interval (95%)
12991	3.2	2.2	1.8-4.5
93530	3.8	1.9	2.6-4.9
93535	3.9	2.7	2.3-5.6
94581	3.4	1.8	2.3-4.5
Erudurudu (Control)	4.2	2.1	2.9-5.4
Serenut 2	2.4	2.2	1.1-3.7
Farmers Own Choice	2.2	1.3	1.4-3.0



Variety	Mean (rank)	Standard Deviation	Confidence Interval (95%)
12991	5.9	1.1	5.5-6.3
93530	3.9	1.9	3.2-4.7
93535	2.8	2.1	2.0-3.6
94581	2.8	1.5	2.2-3.4
Erudurudu (Control)	4.0	1.8	3.3-4.7
Serenut 2	2.2	1.2	1.8-2.7
Farmers Own Choice	2.8	2.0	2.1-3.6

Appendix 28 – Farmer score statistics and box plots



Where V1=12991
V2=93530
V3=93535
V4=94581
V5=Erudurudu (Control)
V6=Serenut 2
V7=Farmers Own Choice

Variety	Mean (weighted score)	Standard Deviation	Confidence Interval (95%)
12991	37.5	12.3	33.3-41.8
93530	33.8	13.6	29.0-38.5
93535	31.7	14.0	26.8-36.5
94581	31.7	15.8	26.2-37.3
Erudurudu (Control)	32.9	17.4	26.8-39.0
Serenut 2	40.2	14.8	35.1-45.9
Farmers Own Choice	29.8	16.2	24.2-35.5

Appendix 29 – Form used for individual farmer assessments

Individual Farmer Assessment Form/Guidance Notes

Farmer No:_________________

Name of Farmer:_____________________________________

Name of assessor ____________________________________

Organisation____

District/County/Subcounty/Parish/Village____

Date of Assessment___________________________________

Guidance Notes

1. Please complete the table on the next page for each individual farmer.

2. Start by asking what characteristics are important in assessing varieties and mark yes or no in the appropriate box.

3. Then ask then to rate the importance of the characteristic on a scale of 0-2. Where 0=not important, 1= some importance and 2=important. Go through and check the scores with the farmer.

4. Ask for the reasons behind the score and note in the appropriate box

5. Add in any missing characteristics mentioned by farmers that are not in the list and again ask for the weighting (0-2) and reason behind the score

7. Then going down the form for each variety (V1-V7) score each characteristic on a scale of 0-2. Where 0=poor performance, 1=average/adequate performance, 2=good/well above average performance. Check each score with the farmer and that the correct variety has been assessed in relation to the field plots

8. Make sure that no characteristics have been missed for any variety and that the farmer believes a proper description and scoring of each variety has been given.

9. Total the scores for each variety.

10. Please pass completed forms to Charles Busolo-Bulafu for processing and analysis together with trial data form (keep both together for the farmer).

Characteristic	Farmer Identified (Y or N)	Farmer Weighting (0-2)	Weighting Reason	V1	V2	V3	V4	V5	V6	V7
Yield (0-2)										
Taste (0-2)										
Colour (0-2)										
Rosette Resistance (0-2)										
Leaf Spot Resistance (0-2)										
Leaf Miner Resistance (0-2)										
Length to Maturity (0-2)										
Seed size (0-2)										
Marketability (0-2)										
Cookability (0-2)										
Ease of Shelling (0-2)										
Ease of Harvesting (0-2)										
Drought resistance (0-2)										
Storability (0-2)										
Germination (0-2)										
Oil content (0-2)										
Drying Performance (0-2)										
Seed coat characteristic (0-2)										
Total Score										

Appendix 30 – Form used for group assessments

Group Farmer Assessment Form and Summary Sheet/Guidance Notes

Name of District:____________________________________

Name of assessors ___________________________________

Organisations____

Date of Assessment__________________________________

Female or male group_________________________________

Guidance Notes

1. Please complete the tables on the next 2 pages for each district grouping (with two groups per District - one of men; one of women).

2. Write the variety numbers of all the varieties on three different coloured manila papers - one for each of the following: poor performance; average/adequate performance; good performance. Get the farmers to vote on each variety (making sure they only vote once) and record the results in table 1 after agreement on the final scores and votes. Present the total weighted scores to the farmers to see iof they think it is a true reflection of the situation. Make any further notes (concerning disagreement or other) under table 1

3. For each variety get farmers to explain why they voted in that way (i.e. to identify the characteristics associated with each). List the characteristics for each variety (1 manila sheet per variety).

4. For each characteristric get farmers to put counters (or seeds or other material) against the importance of each characteristic. Limit the number of counters given to each farmer to one less than the total number of identified charactercics for each variety (this will have to be done for each variety/sheet).

5. Get farmers to discuss the final piles of counters to make sure it is an accurate reflection of their opinions on the determinants of varietal performance.

6. Record the results in table 2 (for ease try to list all characteritics in the same order). Write in any further details concerning this (noting any major disagreements) under table 2.

Table 1 - Summary of Overall Varietal Rankings (total votes by variety and performance)

Variety Number	Score 2 - good performance (weight=2) (Total votes)	Score 1 - average or adequate performance (weight=1) (Total votes)	Score 0 - poor performance (weight=0) (Total votes)	Total Weighted Score (Score in each coluumn X weight and all three added together)
1				
2				
3				
4				
5				
6				
7				

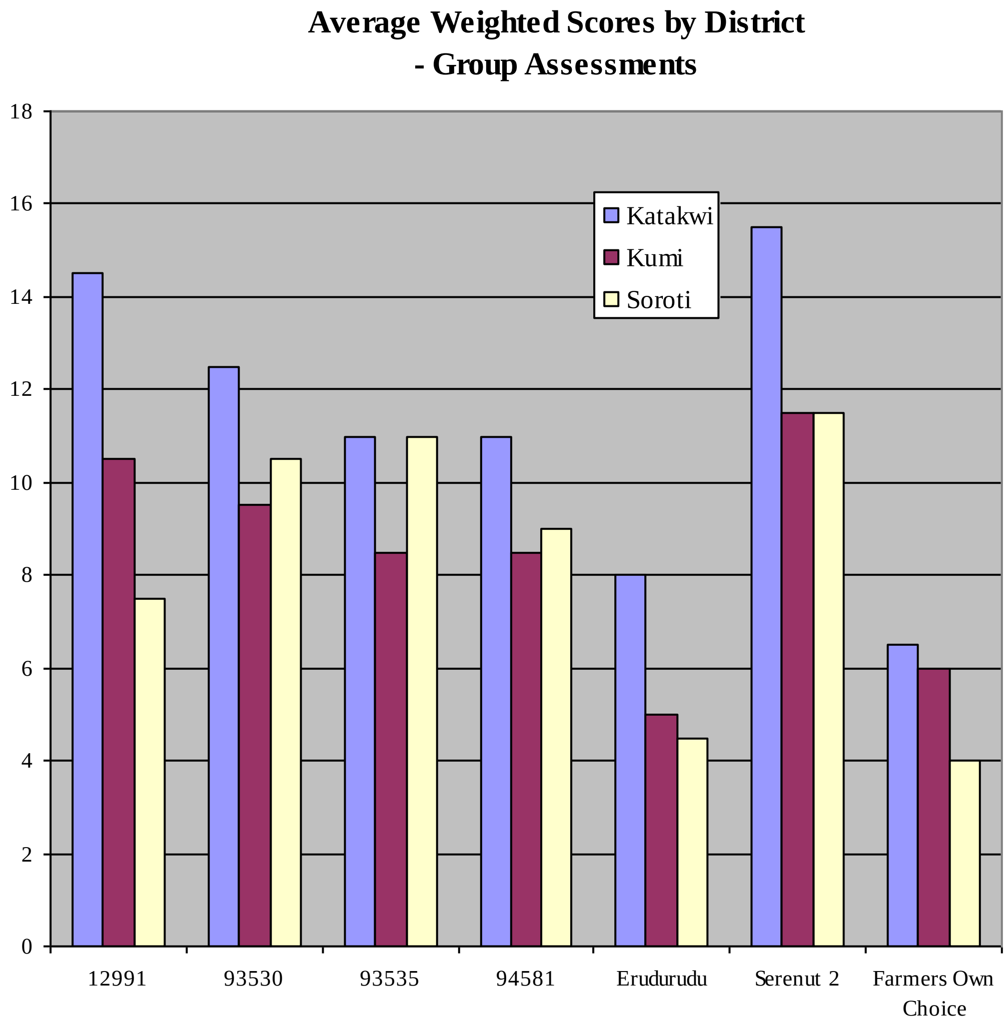
Any further notes on this exercise (disagreements within the group etc.)

Table 2 - Summary of importance of characteristics by variety

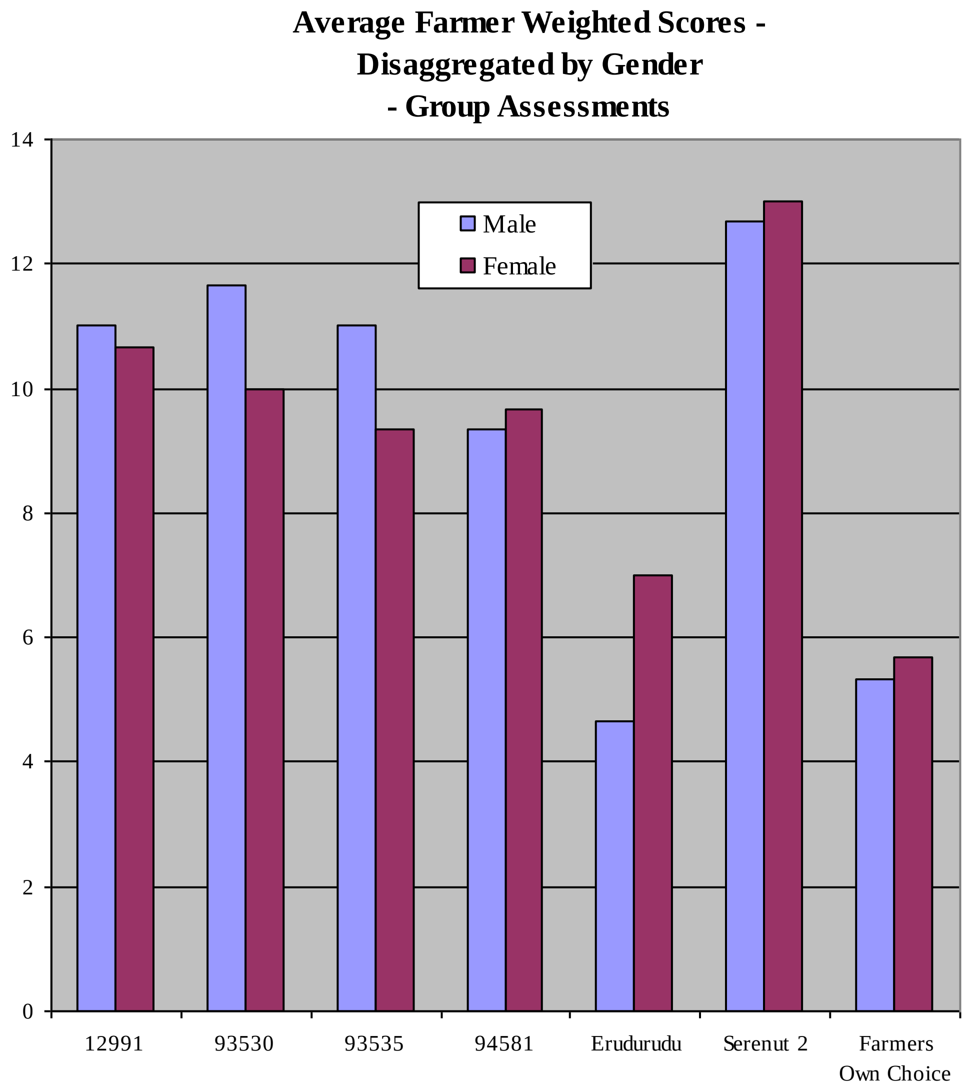
Characteristic (to be written in after identification by farmers)	V1 Counters	V2 Counters	V3 Counters	V4 Counters	V5 Counters	V6 Counters	V7 Counters
Total Score							

Any further notes on this exercise (including significant disagreements)

Appendix 31 – Group assessments by district and gender



Appendix 32 Group assessments: average farmer-weighted scores disaggregated by gender



PLATES

1. Groundnut plants with chlorotic rosette disease symptoms

2. Groundnut plants with green rosette symptoms. Note the severe stunting.

3. On-station trials at SAARI showing replicated plots of test varieties and bulking up plots.

4. On-farm trials in Kumi District being run by a womens' group.

5. On-farm bulking up in Katakwe District. The vector resistant variety, ICG-12991 (Serenut 4T), is on the left.

A farmer collaborator who is keen to test new groundnut varieties