CROP PROTECTION PROGRAMME

PROMOTION OF SUSTAINABLE CONTROL OF COVERED KERNEL SMUT OF SORGHUM THROUGH BROADENING THE CROPPING BASE

R7518 (ZA0361)

FINAL TECHNICAL REPORT

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LIST OF PROJECT PARTNERS

Promotion of sustainable control of covered kernel smut of sorghum through broadening the cropping base

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CPP Production System	Semi-arid

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Acronyms and abbreviations

a.i.	Active ingredient
ARI	Agricultural Research Institute
ARTI	Agricultural Research and Training Institute
CKS	Covered kernel smut
CPP	Crop Protection Programme
CCT	Christian Churches of Tanzania
DALDO	District Agriculture and Livestock Development Officer
DED	District Executive Director
DEDO	District Education Development Officer
DFID	Department for International Development
FAO	Food and Agriculture Organisation
FTC	Farmer Training Centre
g	Grammes
GTZ	German Organisation for Technical Co-operation
KARI	Kenya Agricultural Research Institute
kg	Kilogrammes
NARO	National Agricultural Research Organisation
NAROSEC	NARO Secretariat
NGO	Non Governmental Organisation
NRI	Natural Resources Institute
PRA	Participatory Rural Appraisal
SAARI	Serere Agricultural & Animal Production Research Institute
SDDP	Soroti District Development Programme
SRI	Sugarcane Research Institute
ZCC	Zonal Communication Centre

Executive Summary

Covered kernel smut (*Sporiosorium sorghi*) is a major constraint to yield of small-holder sorghum in semi-arid areas. The fungus is seed-borne and develops systemically as the sorghum crop grows. The teliospores of the fungus replace the grain in the panicle causing direct crop losses in proportion to the area of the panicle infected. Previously disease-free grain can be contaminated during harvest. Thus, covered kernel smut can increase rapidly causing high levels of yield loss and staple food deficits. Suitable seed sanitation practices have been evaluated both on-station and on-farm in Tanzania, Kenya and Uganda. Farmer selection of disease-free seed or use of a fungicide seed treatment will effectively control covered kernel smut.

A core of extension providers in each project location has been trained in the identification and control of sorghum smuts, thereby enhancing the quality of support that can continue to be provided to small-holder sorghum growers. Implementation of farmer-managed trials has ensured that the benefits of seed sanitation practices have been highly profiled in project locations. Promotional activities have included farmer meetings, farmer days and, in Tanzania, two radio programmes and exhibits at the national agricultural shows. A booklet on identification and control of sorghum smut in Dodoma has been produced, pre-tested, revised and distributed in Central Tanzania. A poster has been designed and pre-tested to support the booklet. Both these outputs are produced in Kiswahili. A similar booklet in Ateso has been written for Uganda.

Constraints to uptake of seed sanitation were identified and addressed. In Tanzania, the shortage of food may cause farmers to use selected seed grain as food. Bought-in replacement has high levels of smut. Through the farmer network and National Programme, suitably adapted varieties of cassava have been identified and community cassava nurseries established. Provision of a cassava utilisation workshop generated acceptance of the crop amongst participating farmers. Each participating farmer will receive cuttings from the nursery. This will enable them to establish their own cassava at the end of the present season. The nursery will be retained and provide a supply of cassava cuttings for planting or sale. Videos have been made of cassava agronomy and utilisation.

In Kenya, poor establishment of the second season crop was identified as a constraint to sorghum production. Through on-farm participatory evaluation, suitable varieties and ratooning practices have been identified and tested. The identification of opportunity for farmers to apply seed sanitation practices whilst acting as outgrowers of marketable sorghum in Teso Uganda has encouraged farmer uptake and acceptance.

The extension message has been further promoted through primary schools in Tanzania and Kenya. This has involved a process of engagement with the education sector, which has been well documented and provides a “blueprint” for the use of this type of activity.

Based on the magnitude of the communication channels used, the extension message of selection of disease-free seed has directly reached an estimated 18 000 households. The message will reach a considerably greater number of households through the project videos and radio broadcast. The requirement for scaling-up of these achievements to other areas has been identified.

Background

Sorghum (*Sorghum bicolor* (L) Monarch) is one of the world's major food crops, particularly in areas of high temperature and low rainfall. Global production is estimated to exceed 40 million hectares, ranking it fifth in importance among cereals (FAO, 1992). It is relatively drought tolerant and can therefore be grown in marginal, semi-arid areas where rainfall is unreliable and the cultivation of food crops such as maize is not practical. Sorghum is very versatile as a food and feed grain and exhibits wide adaptation and yield stability in marginal areas where it is used as a subsistence staple. As a consequence, sorghum is important in traditional, low input, cereal based, semi-arid production farming systems in Africa. (Norman, Pearson and Searle, 1984).

Forty-one percent of the world-wide area of sorghum production is located in Africa (Dogget, 1988). East African countries (Burundi, Ethiopia, Kenya, Uganda, Sudan and parts of Tanzania) collectively produce about 4 million tonnes of grain sorghum per year on just over 6 million hectares of land (Guiragossian, 1986).

The yield from sorghum is potentially very high (Fisher and Wilson, 1975) and can average 4 505 kg ha^{-1} in the USA (FAO, 1992). However, average yields in Africa have been estimated at 803 kg ha^{-1} (the lowest globally) and are tending to decline (Dogget, 1988). The reasons for this are that resource poor, smallholder farmers do not have recourse to external inputs, statutory support, efficient communications or markets. Further, small-holder sorghum production has tended to rely on tall, late-flowering landrace cultivars. These have been selected for their local adaptation, high grain quality and resistance to pre- and post-harvest pest and disease losses rather than their physiological yield potential.

The trend since the early 1970's has been for an increase in maize production leading to the domination of this crop in many cereal-based cropping systems in Africa, often adversely affecting interspecific genetic diversity and food security (Jaffee, 1992; Drinkwater, 1994). As the importance of diversification of agricultural production and the requirement to improve productivity of traditional crops such as sorghum has become more appreciated (Jaffee, 1992), the demand for cultivars with high productivity and environmental stability has increased (Duncan and de Milliano, 1995). As a result, National and International sorghum development programmes have been initiated or expanded (Appa Rao *et al*., 1998) leading to development of new varieties. The newly developed varieties include traits such as shorter stems, more compact heads, earlier maturity and higher yields as well as improved resistance to grain weathering, improved response to fertilisers and enhanced production technologies (Doggett, 1988: Andrews, Mughogho and Ball, 1984: Appa Rao *et al*., 1988).

There is an unusually broad range of diseases potentially affecting sorghum crops which is a reflection on the diversity of production and utilisation practices and environments in which this crop is cultivated. In areas where sorghum is traditionally grown, plants may be attacked by five or six foliar pathogens, an array of soil-borne organisms, a mycoplasma and at least two systemic fungal diseases (Frederiksen,1986). Although there is little evidence to suggest that disease problems threatened traditional sorghum production, the selection of improved and genetically uniform cultivars has led to the expansion of a range of biotic pressures including plant disease (ICRISAT, 1992: Frederiksen *et al*., 1995).

There are four smuts infecting sorghum in Africa. *Sphacelotheca sorghi = Sporiosorium sorghi* (covered kernel smut), *S. cruenta* (loose kernel smut), *S. reiliana* (head smut) and *Tolyposporium ehrenbergii* (long smut). All four are of importance in different areas. Tarr (1962) reported incidences ranging from 8 - 43 % for covered kernel smut (CKS), which is considered a priority

disease in eastern Africa (de Milliano, 1992: Guiragossian, 1986). Surveys in Kenya and Tanzania have indicated that sorghum smuts, especially CKS are widespread and cause significant yield losses in Eastern and Central zones where it is present on 30 % of fields (Frowd, 1978: Mbwaga *et al*., 1993).

Covered kernel smut (*S. sorghi*) is generally distributed in every sorghum growing region of the world (Frederiksen, 1986). The disease may be controlled by treatment of seed with a suitable fungicide such as thiram. However, this has not been widely adopted by the target groups i.e. resource poor, smallholder farmers in Kenya,Tanzania and Uganda.

From 1995 –1998, CPP funded collaborative work between NRI and KARI, Katumani, Kenya and ARTI, Ilonga, Tanzania "An investigation into the epidemiology and control of fungal pathogens of sorghum in semi-arid production systems in East Africa" (ZA009 / R6581). As part of these activities, socio-economic surveys were undertaken in Dodoma region, Tanzania and Mwingi District Kenya. CKS was identified as one of the more damaging diseases of sorghum in these areas. On-station and on-farm activities were undertaken in both countries and potential disease control strategies suitable to the resource-poor, small-holder farmers in Kenya and Tanzania identified.

In Kenya, a series of women's / self-help groups was established in Mwingi District. Each group (*c*. 10 members) had an on-farm trial plot in which the performance of selected sorghum lines was compared under local agronomic and environmental conditions. Crops were also grown from fungicide treated and untreated seed to enable farmers to demonstrate and evaluate the role and effect of a fungicide seed dressing on control of this cereal pathogen. The visits to these sites by the farmer groups, national extension officers, Kenyan and UK researchers facilitated discussion of pathology and agronomy aspects in an informal farmer-led setting. The value of seed treatments in control of this disease was demonstrated and farmers became familiar with different aspects of the disease cycle, symptom identification, rouging etc.

Successful implementation of such control strategies involves an appreciation of the life cycle of the pathogen, knowledge of the control strategies and health and safety measures associated with control strategies. "Getting the message across" to farmers was addressed in Kenya by uptake pathways, not only with those presently involved in crop production, but also through schools in the region. Information on the disease cycle and control measures was provided to primary school teachers who worked with pupils to produce short plays on control of sorghum smut. The plays from each school were presented before parents and judges and small prizes awarded. In this manner, information was disseminated to a greater number of farmers through watching their children's plays. These activities provided a valuable, non-didactic input to primary education in the region, whilst also providing valuable information to pupils many of whom will be involved in sorghum husbandry in the future. In a secondary school, classes with older students were held on disease development and the students worked in groups to produce disease control posters. The older students then took part in similar activities with younger students. This pilot dissemination activity appeared very well received and it is thought that this may be further developed during future activities.

In Tanzania, it was found that use of seed treatments was less appropriate. This was a consequence of socio-economic factors including the relatively higher price of pesticides in relation to farmers' incomes, limited availability of product and inappropriately large units of product i.e. minimum 5 kg, and more limited access to market. A potential control strategy identified through R6581 is based on the seed sanitation practice "clean-head selection". Normally, farmers harvest all their sorghum together, pile it into a heap and remove it from the

field for threshing. Smut spores are released during this process and previously smut-free grain may be contaminated with spores. Clean-head selection involves farmers selecting smut-free sorghum heads and removing these prior to the main harvesting operations. They are thus not contaminated by the spores released during harvesting and threshing and may be used as a source of smut-free seed for the following season's sorghum crop. Preliminary on-farm studies revealed incidences of CKS of up to 17 %. Clean head selection significantly reduced this. Clean head selection represents an appropriate technology for the reduction of CKS on sorghum in smallholder crops in Dodoma region of Tanzania. The requirement is to fully-validate and promote this technology and facilitate its uptake. Promotion activities in the project include further on-farm activities and access to the next generation, building on the project team's experience from activities in Kenya.

Poor household food security was identified as being, potentially, the main constraint to uptake of clean head selection in Dodoma Rural. Although farmers may save clean seed, there is such pressure on household food reserves towards the end of the off-season that the selected seed is consumed by family members. This necessitates purchase of seed from market or neighbours at the commencement of the rains season which is contaminated with the pathogen. Effective promotion of the clean seed technology required provision of an additional food source to sustain households in the of-season. This need was recognised by the Ministry of Agriculture and Food Security. The identified approach for the project, supported by Dr Mitawa (Deputy Commissioner, Ministry of Agriculture and Co-operatives, Tanzania) is to promote cassava production in Dodoma. As cassava stores well, it could provide food in the off-season reducing the temptation to consume seed from the clean sorghum heads which have been selected for seed for the next season's crop.

A need for research into sorghum smut diseases in Uganda was identified through the DFID-funded needs assessment "*Aijul Eode*" undertaken in February 1998 by NARO staff and consultants. In this assessment, sorghum emerged as one of the crops of major importance which had also ranked highly on NARO's 1994 research commodity prioritisation.

References

ANDREWS, D.J., MUGHOGHO, I.K. and BALL, S.L. (1989). 'Sorghum and pearl millet production in Africa: Problems and prospects with new varieties'. In, D.L. Hawksworth (ed), *Advancing Agricultural Production in Africa*, pp 174-186. Wallingford: CAB International.

APPA RAO, S., HOUSE, L.R. AND GUPTA, S.C., (1988). *Review of Sorghum, Pearl Millet and Finger Millet Improvement Programmes in SADCC countries*. SADCC/ICRISAT Sorghum and Millet Improvement Programme, Box 776, Bulawayo, Zimbabwe. 170pp.

DE MILLIANO, W.A.J. 1992. Sorghum diseases in southern Africa. Pages 9-19 in Sorghum and Millets: A Second World Review. (de Milliano, W.A.J., Frederiksen, R.A., and Bengston, G.D., eds.). Patancheru, A.P. 502 324, International Crops Research Institute for the Semi-Arid Tropics.

DOGGET, H. 1970. Downy mildew in East Africa. Indian Phytopathology 23: 350-355.

DOGGETT, H., 1988. *Sorghum*, 2nd Ed. Tropical Agriculture Series. Harlow: Longman. 512pp.

DRINKWATER, M., 1994. Knowledge, conciousness and prejudice: adaptive agricultural research in Zambia. In, I. Scoones and J. Thompson (eds), *Beyond Farmer First: Rural People's Knowledge, Agricultural Research and Extension Practice'.* London: Intermediate Technology Publications.

DUNCAN, R.R. and DE MILLIANO, W. A. J. 1995. Plant disease control in sorghum and pearl milleta. In, J.F. Leslie and R.A. Frederiksen (eds), *Disease Analysis through Genetics and Biotechnology: Interdisciplinary Bridges to Improved Sorghum and Millet Crops*, pp 35-71. Ames: Iowa State University

FAO. 1992. FAO Production Yearbook, vol. 46. Rome: FAO.

FISCHER, G.W. 1936. The longevity of smut spores in herbarium specimens. Phytopathology 26: 1118-27

FISHER, K.S. and WILSON G.L., (1975). 'Studies of grain production in *Sorghum bicolor* (L. Moench): III'. *Australian Journal of Agricultural Research*, 26, 31-41.

FREDERIKSEN, R.A. 1986. Compendium of sorghum diseases. American Phytopathological Society. Minnesota. USA.

FREDERIKSEN, R.A., THOMAS, M.D., BANDOPADHYAY, R. and MUGHOGHO, L.K., 1995. 'Variable pathogens of sorghum'. In, J.F. Leslie and R.A. Frederiksen (eds), *Disease Analysis through Genetics and Biotechnology: Interdisciplinary Bridges to Improved Sorghum and Millet Crops*, pp 11-24. Ames: Iowa State University.

FREDERIKSEN, R.A., and REYES, L. 1978. The Head Smut Program at Texas A & M University. Pp 367-372. In: Sorghum Diseases, A World Review. Proceedings of the International Workshop on Sorghum Diseases, 11-15 December 1978, ICRISAT, Hyderabad, India, Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

FROWD, J.A. 1978. A world review of sorghum smuts. Pp 331-338 In Sorghum Diseases, A World Review. Proceedings of the International Workshop on Sorghum Diseases, 11-15 December 1978, ICRISAT, Hyderabad, India, Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

GUIRAGOSSIAN, V. 1986. Sorghum production constraints and research needs in eastern Africa. Pages 28-46 in Proceedings, Fifth Regional Workshop on Sorghum and Millets Improvement in Eastern Africa, 5-12 July 1986, Bujumbura, Burundi.

HASSAN, S.F., KHAN ZIA, N.A., ARSHAD KHAN, M., UBAIDAL ISLAM, A.N.M. and KHAN, M.A. 1970. Floral infection of sorghum with long smut *Tolyposporium sorghi* Kuhn (Pat.). Journal of Agricultural Research, Punjab 8: 411-412.

ICRISAT, 1992. Sorghum and Millets Diseases: A Second World Review. (de Milliano, W.A.J., Frederiksen, R.A., and Bengston, G.D., eds.). Patancheru, A.P. 502 324, International Crops Research Institute for the Semi-Arid Tropics

JAFFEE, S., 1992. 'Enhancing agricultural growth through diversification in sub-saharan Africa'. In, S. Barghouti, L. Garbus and D. Umali (eds), *Trends in Agricultural Diversification: Regional Perspectives*. New York: World Bank Technical Paper 180.

KING, S.B. 1972. Major cereals in Africa. 1970 and 1971. 7th and 8th Annual Reports of the AID-RS Project

MANZO, S.K. 1976. Studies of the mode of infection of sorghum by *Tolyposporium sorghi*, the causal organism of long smut. Plant Disease Reporter 60: 948-952

MBWAGA, A.M., PANDE, S., DE MILLIANO, W.A. and KARUNAKAR, R.I., 1993. Diseases amd parasitic weeds of sorghum in Tanzania. Occurrence and incidence, 1986 - 1990. Crop Protection, 12:183-188.

McKNIGHT, T. 1966. Studies on the fungus *Sphacelotheca sorghi* (Link) Clint. 1. Effect of position of inoculum and stage of development of the germinating seed on infection. Queensland Journal of Agricultural and Animal Science 23: 605-607

NJUGUNA, J.G.M., MUGHOGHO, L.K, GUIRAGOSSIAN, V. and ODHIAMBO, R.O. 1992. Studies on the biology of long smut of sorghum caused by *Tolyposporium sorghi*. Page 292 in Sorghum and Millets Diseases: A Second World Review. (de Milliano, W.A.J., Frederiksen, R.A., and Bengston, G.D., eds.). Patancheru, A.P. 502 324, International Crops Research Institute for the Semi-Arid Tropics.

NORMAN, M.J.T., PEARSON, C.J. and SEARLE, P.G.E., 1984. 'Sorghum'. In, *The Ecology of Tropical Food Crops*, pp 120-136. Cambridge University Press

RAGAB, M.A. and MAHDI, M.T. 1966. Studies of on *Tolyposporium ehrenbergii*, the cause of long smut of sorghum in Egypt. Mycologia 58: 184-191

TARR, S.A.J. 1962. Diseases of sorghum, sudangrass and broomcorn. Kew, Surrey, England: Commonwealth Mycological Institute. 380 pp.

WILSON, J.M. and FREDERIKSEN, R.A. 1970a. Histopathology of the interaction of *Sorghum bicolor* and *Spacelotheca reiliana*. Phytopathology 60: 828-832.

Project Purpose

Production System:	Semi-arid
Programme Purpose:	Variability and seasonality of principal diseases of cereals identified, crop loss assessments generated and disease management models developed and promoted and improved methods for the management of principal plant diseases of cereal-based cropping systems (including legume crops) developed and promoted.
Project Purpose:	Promotion of strategies to reduce the impact of pests and stabilise yields in semi-arid,cereal-based cropping systems, for the benefit of poor people.
Specific Research Objectives:	To further develop and promote technologies for the reduction in seed-borne inoculum of covered kernel smut of sorghum to enhance food security. Work in Kenya and Tanzania to promote the practice of using smut-free seed to establish crops through on-farm trials and access to the next generation. In Kenya, evaluate the potential of ratooning to enhance food security. In Tanzania, broaden the cropping base to include cassava to enable farmers to save quality sorghum seed for planting. To evaluate the significance of sorghum smut in Teso, Uganda and initiate on-farm studies.

Sorghum is an important food crop within traditional low input cereal-based farming systems in Africa where 41 % of the world-wide area of this crop's production is located. It is relatively drought tolerant and can be grown in marginal semi-arid areas where the rainfall is unreliable and precludes growing other crops such as maize. Food security issues have prompted many of the African national programmes as well as international programmes such as ICRISAT, to actively encourage farmers to grow sorghum. Crop improvement programmes have prioritised on selection of improved lines and dissemination of germplasm. However, limited resources within many of the national programmes has resulted in a need for identification and promotion of suitable technologies to reduce crop losses by pests and diseases.

The earlier project (R6518) contributed to the Programme Output. The key foliar and panicle diseases affecting sorghum in Tanzania and Kenya were identified. Their importance was prioritised and studies undertaken to elucidate their biology and potential control options. The PRA and disease surveys undertaken in Kenya and Tanzania highlighted covered kernel smut as a major disease constraining yields of smallholder sorghum. Initial work was therefore undertaken on control of CKS through reduction of inoculum on seed used to establish crops through either seed treatment (Kenya) or clean-head selection (Tanzania). However, there was still a need to enable uptake of these technologies by resource poor, smallholders.

In the project reported here (R7518), the constraints to uptake of suitable seed sanitation practices for the control of CKS have been identified. The practice of enhancing sustainable crop production in Kenya through ratooning sorghum has been evaluated using both on-station and on-

farm participatory activities. The DFID-funded needs assessment for agricultural research in the Teso farming system "*Aijul Eode*" identified sorghum as a key crop and highlighted a requirement for research into control of smut diseases. The relative importance of the different sorghum smut diseases and their control has been identified through disease survey and PRA, and seed sanitation practices validated in Teso.

Constraints to uptake and adoption of suitable seed sanitation practices have been addressed through a variety of innovative methods. The practice of ratooning in Kenya reduces the use of seed treatment chemicals by 50 %. In Tanzania, provision of an additional crop, cassava, addresses household food security issues and enables the farmer to save disease-free sorghum seed from one season to the next.

Promotion and dissemination of the sustainable control of CKS is supported by a communication strategy including posters, booklets and leaflets produced in English, Kiswahili and Ateso. Promotion and dissemination is also enhanced through partnerships with schools and teaching professionals to provide information for " tomorrow's farmers, today".

Adoption of sustainable control practices for CKS will promote the sustainability of smallholder sorghum production in Tanzania, Kenya and Uganda and contribute to the goal of sustaining rural livelihoods in semi-arid, sorghum-based farming systems.

The project has achieved this through delivering the following:

Output 1: Evaluation of the significance of sorghum smut and potential control options in Uganda,

Output 2: Investigation of varietal resistance to smut and pathogen variability in Uganda,

Output 3: Promotion and dissemination of developed control strategies for CKS in Kenya and Tanzania,

Output 4: Evaluation of sorghum ratooning for enhancement of food security in Kenya,

Output 5: Broadening the cropping base to enhance food security in sorghum cropping systems in Tanzania.

PROJECT ACTIVITIES

Output 1: Evaluation of the significance of sorghum smut and potential control options in Uganda

Activity 1.1: Participatory Rural Appraisal

A PRA exercise was conducted in Teso, Uganda to assess farmer problems and practices in relation to sorghum pathogens and pests. This activity was led by the NARO socio-economist, Mr G Kibayo previously based at NAROSEC. The study was undertaken to build on the information available from the DFID-funded needs assessment (1998) in respect of sorghum. The PRA was focussed to avoid duplication of the cropping, household and socio-economic information gathered by other CPP funded work in the Region (R7445).

Staff of SAARI, NRI, NAROSEC and participating NGOs (Concern) held a meeting on 12 April 2000 to formulate a checklist and questionaire for a focussed PRA to assess the major constraints to sorghum production with particular reference to sorghum smut diseases. The aim of the survey was to determine farmer perception of constraints to sorghum production and yield with particular reference to sorghum smuts.

Farmer group interviews were held in each of two villages in four Districts as shown in Table 1. The exercise was conducted between 13-17 April 2000.

Table 1: Locations of group farmer interviews, Teso (April, 2000)

District	Sub-county	Village
Katakwi	Katakwi	Aparisia
Katakwi	Wera	Opiriai
Soroti	Soroti	Omalera
Soroti	Kaberamaido	Odiope
Kumi	Kumi	Okouba
Kumi	Atutur	Akalabai
Pallisa	Agule	Chelekura-A
Pallisa	Agule	Kopuwai

The report of this activity may be found in Appendix 1

Activity 1.2: Disease survey

This study was undertaken by a team comprised jointly of NRI and SAARI staff in July 2000. The survey covered the same districts as the PRA. In addition to providing quantitative information about the incidence of covered kernel smut, the survey was used to gain information on key areas identified in the PRA including varieties grown, seed selection and crop rotation. Farmers had cited *Emoto* (the parasitic weed *Striga*) as a problem and the opportunity was taken to gather quantitative information on the incidence of both *Striga asiatica* and *S. hermonthica*.

The survey centered on 2-3 clusters in each district. A cluster included fields in or around one or two villages. A representative interview for each cluster was undertaken to ensure adequate recording of the rotation practiced, sorghum varieties grown and sources of the seed used.

The report of this activity may be found in Appendix 2.

Activity 1.3: Stakeholder workshop

A workshop was convened at SAARI, Serere on 21 April 2000 to which representatives of SAARI, NRI, participating NGOs (Concern), Extension and Farmers were invited. The results of the PRA were presented and a written summary provided for each participant. The workshop included an introduction to the biology and control of sorghum smuts. Discussions focussed on how the project activities and goals interacted with the farmers' and NGOs' priorities.

The summary report is presented in Appendix 1.

Activity 1.4: Feed-back to communities through village / farmer meetings

Staff of SAARI, NRI and extension visited two locations in Pallisa and two in Katakwi in April 2001 and April 2002 and addressed four farmer groups on the identification and control of sorghum covered kernel smut.

Activity 1.5: Use of farmers' seed for on-station validation of seed sanitation practices

An experiment was established at SAARI, Serere in September 2000 to provide information on the role of seed-borne inoculum on subsequent incidence of covered kernel smut of sorghum. The experiment used seed of known varieties sourced in July 2000 from farms with a high or a low incidence of covered kernel smut. Seeds of white sorghum cv. Enyang and red sorghum cv. Eyera collected from a location in Soroti (farmer 10) with a high disease incidence (40 %). Seed of the same varieties were collected from Pallisa (farmer 19) with an average disease incidence of 4 %. In this manner four seed stocks were obtained as follows:
Stock A: White sorghum cv. Enyang, low seed-borne inoculum,
Stock B: White sorghum cv. Enyang, high seed-borne inoculum,
Stock C: Red sorghum cv. Eyera, low seed-borne inoculum,
Stock D: Red sorghum cv. Eyera, high seed-borne inoculum.
Each seed batch was divided into two portions. One portion was dusted with the fungicide thiram at a rate of c. 3 g a.i. kg^{-1} and the other left untreated. This gave eight treatment combinations for the first season. In the second and third season a third treatment combination was included. This involved replanting seed saved from crops grown from thiram treated seed to which no additional fungicide seed dressing had been applied.

The treatments are shown below (Table 2).

Table 2: Treatments used for the evaluation of control of seed-borne covered kernel smut of sorghum, SAARI, Uganda

Season 1 September 2000 – February 2001

Treatment No.	Sorghum cultivar	Disease incidence in source crop	Chemical treatment
1	Enyang	low	none
2	Enyang	low	Thiram
3	Enyang	low	Thiram
4	Enyang	high	none
5	Enyang	high	Thiram
6	Enyang	high	Thiram
7	Eyera	low	none
8	Eyera	low	Thiram
9	Eyera	low	Thiram
10	Eyera	high	none
11	Eyera	high	Thiram
12	Eyera	high	Thiram

Season 2 August 2001 – December 2001

Treatment No.	Sorghum cultivar	Disease incidence in source crop	Chemical treatment
1	Enyang	T1	none
2	Enyang	T2	None this season
3	Enyang	High	Thiram
4	Enyang	High	none
5	Enyang	T2	None this season
6	Enyang	High	Thiram
7	Eyera	T1	none
8	Eyera	T2	None this season
9	Eyera	High	Thiram
10	Eyera	High	none
11	Eyera	T2	None this season
12	Eyera	High	Thiram

Season 3 February 2002 – July 2002

Treatment No.	Sorghum cultivar	Disease incidence in source crop	Chemical treatment
1	Enyang	T1	none
2	Enyang	T2	None this season
3	Enyang	High	Thiram
4	Enyang	High	none
5	Enyang	T2	None this season
6	Enyang	high	Thiram
7	Eyera	T1	none
8	Eyera	T2	None this season
9	Eyera	high	Thiram
10	Eyera	high	none
11	Eyera	T2	None this season
12	Eyera	high	Thiram

The treatments were laid out as a fully randomised complete block design in which each treatment was replicated once. Each plot consisted of five rows, 10 m in length of sorghum spaced 0.2 m apart. Each plot was separated from its neighbours by five guard rows of maize. Maize variety Kwanda composite was used, as it is equally as tall as the traditional sorghum varieties.

The effect of these treatments on incidence of covered kernel smut was assessed at crop maturity on 50 plants randomly selected from the inner three rows of each plot.

Output 2: Identification of varietal resistance to smut and pathogen variability in Uganda

Activity 2.1: Screening for varietal resistance to covered kernel smut

A trial was planted at SAARI, Serere on 10 October 2000 to evaluate the performance of 185 advanced breeding lines at this location. Seed was inoculated with teliospores of covered kernel smut according to the method of Selvaraj (1980). Three replicate plots (5 x 5 m) were planted using fungicide treated and three of untreated seed for each line. The aim was to identify promising varieties in terms of yield, quality and covered kernel smut resistance. This information would feed-back into the SAARI sorghum improvement programme.

Additionally, data on the incidence and severity of covered kernel smut in farmers' field was analysed with respect to variety. This latter exercise was to determine whether there was a link between variety and incidence of covered kernel smut in the germplasm to which farmers presently have access.

Activity 2.2: Evaluation of pathogenicity of a range of isolates to a range of sorghum cultivars

The intention here was to select promising lines from activity 2.1 and to determine the genetic variability of this germplasm to isolates of *S. sorghi* isolated during the July 2000 disease survey.

Output 3: Promotion and dissemination of developed control strategies for covered kernel smut in Kenya and Tanzania

Activity 3.1: Promotion of control strategies for covered kernel smut in Kenya

On-farm participation

Promotion of suitable seed sanitation practices for the control of covered kernel smut of sorghum was undertaken a) through linking with other initiatives in the region b) through on-farm promotion in conjunction with activity 4.2.

Access to the next generation (inter-schools drama competitions)

Inter-school drama competitions were arranged in Kiomo village and Katse village and involved three and five schools respectively. These were organized in liaison with the local agriculture, education and chief offices to ensure a smooth course for the competitions. All the primary schools within an educational zone were invited to create a 15-20 minute play in the local language based on the extension message, then to compete against each other in a competition for prize money. The competition rules were:

- The play must not include more than 25 children;
- The play will last for no longer than 20 minutes;
- The play must include the extension message(s);
- The play is to be in the local tongue;
- The judge's decision is final;

The prizes were presented on the day to the headmasters of the schools involved, with the winning schools receiving 2500/-, the runners up 2000/- and the other participating schools each receiving 1500/-;
The prize money was to be spent on the school.

For each competition, a meeting was held for all the headmasters where the details of the arrangements of the competition were decided, and the extension message explained both verbally and distributed in leaflet form. The competitions were held at a central location, where the local communities were invited to support their schools. The judging was carried out by three independent judges, one from KARI, one from a local education office and one from the district extension office. This activity was undertaken during March 2002.

Impact assessment of interschools drame competitions

An impact assessment of the activity was undertaken to determine the value of this method for the dissemination of agricultural information. The assessment was undertaken by Mrs Ester Njugana, head of socio-economics at KARI, Katumani. Mrs Njugana was briefed in general terms on the project activities and involved in judging the inter-schools drama competitions. The three groups for assessment were identified as the farmers who watched the plays, the children who

participated in them and the staff of the agriculture and education departments. The opinions of the farmers were gained through a focussed discussion developed around a checklist. The agricultural and extension staff views were sought through a questionaire. The views of the school children themselves were obtained through less formal group discussion after the drama competition.

Activity 3.2: Promotion of control strategies for covered kernel smut in Tanzania

Identification of school partnership

The participation of schools in the project activities in Tanzania was suggested to the Ministry of Agriculture and Food Security during the identification and development of R7518. Both of the NRI staff involved in this project have considerable experience in vocational agricultural education, which was considered an important dimension to the collaborative work. The Ministry of Education, Tanzania, has a policy of introducing agricultural subjects into the school curriculum depending on the needs in their locality. Thus provision of agricultural information such as identification and control of covered kernel smut to teaching professionals is in keeping with the remit of both the Agriculture and Food Security, and the Education Ministries.

During the first season of on-farm trials (November 1999 – May 2000), supporting information was obtained on the efficacy of seed sanitation practices for control of covered kernel smut in Msanga, Mlowa Barabarani, Mpalanga and Bihawana. This ensured that the project had current validation of the extension message to support the request to develop school-based activities in Dodoma Rural.

Permission was obtained for project activities from the District Executive Director (DED) for Dodoma, after which the District Education Development Officer (DEDO) was consulted. An initial process of engagement was agreed as follows:

1. Identification of 15 primary schools within Dodoma Rural through the DEDO;
2. Provision of a workshop to:

a) provide background knowledge of the project R7518,
b) impart technical information on the significance, identification and control of sorghum covered kernel to teaching professionals,
c) facilitate development of an agreed action plan for incorporation of awareness and control of covered kernel smut into the teachers' professional activities.

Training and development of action plan (First teachers' workshop)

A workshop was held at the Farmer Training Centre, Bihawana on 24 June 2000. The workshop involved 20 teaching staff and ten extension officers. The programme was:

1. Opening remarks (District Agriculture and Livestock Development Officer (DALDO))
2. Objectives of the training day (Dr Mbwaga)
3. Introduction to the sorghum smut project activities (Dr Hayden)
4. Importance of sorghum and the problem posed by covered kernel smuts (Mr Semweiko)
5. Control options available for smut diseases (Dr Mbwaga)

Lunch

6. Introduction to the FTC, smut control trials and disease assessment (Mr Waziri)

7. Practical session for teachers and extension on sorghum smut identification at the FTC field site

Break

8. Overview of sorghum smut identification and control through question and answer sessions with researchers, extension and teachers
9. Teachers view on methods by which knowledge of identification and control of covered kernel smut could be incorporated into their school activities
10. Agree action plan

Close

Moving forward (Second teachers' workshop)

A second teachers' workshop was held on October 6 and 7, 2001. This was attended by fifteen of the school teachers from participating schools in Dodoma Rural. The research staff involved in Project R7518 from both UK and Tanzania attended. Five of the Dodoma Rural Extension staff involved in the farmer participatory work undertaken as part of the project activities also attended.

The objectives of the workshop were:

To provide a forum for teachers to present experiences of incorporating awareness and control of sorghum smut diseases into their teaching activities;
To enable teachers to compare experiences and exchange information to enable them to enhance their own teaching;
To gain information on different teaching methodologies used and the appropriateness of this means as a pathway for dissemination of information / project outputs;
To determine how to proceed in the coming academic year and how to document activities.

The programme was:

<u>Day 1 Shaping and Sharing Teachers' Experiences</u>

Welcome and Introduction	DALDO
Objectives of the Workshop	Dr Mbwaga
Self Introductions	All
Individual Presentations of the Experiences of Participating Teachers	Teachers

Coffee

Key Note Address	DALDO
Group Discussions on Teaching Methods	Teacher groups
Presentations of Group Discussions on Teaching Methods	Group Chairperson

Lunch

Presentations of Group Discussions continued

Question and Answers on Teaching Methodologies All

Tea

Group Discussions on Best Practices
(Consensus Session) All

Day 2: Moving forward

Welcome (Hamisi Makota representing District Educational Development Officer)
Working Groups explored the further development and exploitation of resources and linkages

Coffee

Group Presentations

Lunch

Discussion of Presentations
Consensus Session (Moving forward)
Closing

Implementation and monitoring of school-centred activities

Participants of the workshop in October 2001 were provided with short questionaires to obtain information on the effectiveness of the initial training provided for teachers, quantification of the range of teaching methods used, and potential magnitude of the communication channel.

Schools centred activities were documented between October 2001 – June 2002. Activities were monitored by feed-back gained through visits from the research, extension and zonal communication office partners during that period.

The school activities were reviewed at the project conclusion workshops held in August 2002.

Output 4: Evaluation of sorghum ratooning for enhancement of food security in Kenya

Activity 4.1: On-station evaluation of ratooning

In Kenya, the practice of ratooning of sorghum has been evaluated as this may potentially enhance food security. Seed that is free from inoculum of covered kernel smut was used to establish sorghum crops in the short rains (October – February). The sorghum was subsequently ratooned to facilitate a second crop in the long rains (March – July). Adoption of this practice could potentially ensure optimum use of disease-free seed stocks. In situations where farmers use fungicide seed treatment, adoption of ratooning has, in effect, cut fungicide usage by 50 %. However, the practice of ratooning potentially provides a "green-bridge" for carry-over of both covered kernel smut and stem borers from one season to the next.

In order to promote ratooning, there was a requirement for baseline data to establish the relative effects of covered kernel smut and stem borers on ratooned versus direct sown sorghum.

An on-station trial was implemented at KARI, Katumani in which crops were established by direct seeding for two consecutive seasons, or from seed in the short rains (October – January) and ratooned for the second long rains season (March – July).

The experiment was laid out in the design of a fully randomised complete block. There were four blocks in which each treatment was replicated once. Sorghum variety Seredo was used in all the experimental treatments. Each treatment plot measured 12 m x 3 m.

Treatment combinations are given in Table 3.

Table 3: Treatments used in the comparison of sorghum ratooning versus direct planting on the incidence of sorghum covered kernel smut and stem borers, KARI, Kenya

Treatment No.	Planting date (month)	Ratooning date (month)	Harvesting date (month)	Chemical treatment
1	1) October 2) March	N/A	1) January 2) July	None
2	1) October	2) January	1) January 2) July	None
3	1) October 2) March	N/A	1) January 2) July	Thiram
4	1) October	2) January	1) January 2) July	Thiram
5	1) October 2) March	N/A	1) January 2) July	Carbofuran
6	1) October	2) January	1) January 2) July	Carbofuran
7	1) October 2) March	N/A	1) January 2) July	Buldock
8	1) October	2) January	1) January 2) July	Buldock
9	1) October 2) March	N/A	1) January 2) July	Thiram/ Carbofuran/ Buldock
10	1) October	2) January	1) January 2) July	Thiram/ Carbofuran/ Buldock

The incidence of covered kernel smut and stem borers were recorded for each treatment at the end of both seasons. Observations were made on the establishment and yield potential of these crops. The most important contrasts were between the "blanket protection" (T9 & T10) and the treatments which did not include a CKS control element.

Activity 4.2 On-farm evaluation of ratooning in Mwingi district, Kenya

Baseline information

Baseline information on the current status of ratooning practices was collected during a focussed survey of 30 farmers in two locations, Nguuku (Mumomi division) and Kamuwongo (Kyuso division). A checklist was developed in association with KARI socio-economic staff and district extension staff. This was used as the basis for the individual farmer interviews undertaken in October 2000.

First cycle of on-farm work (October 2000 – January 2001, March – July 2001)

Based on the new knowledge generated through the baseline survey, a range of possible ratooning practices was identified. The practices were subsequently evaluated on-farm. The ratooning treatments were as follows:

- Treatment 1: (variety Seredo) stalks cut at harvest, subsequent tillers not thinned,
- Treatment 2: (variety Seredo) stalks cut at harvest and the tillers thinned to the four youngest at the on-set of the long rains,
- Treatment 3: (variety Seredo) stalks removed just before the on-set of the rains,
- Treatment 4: (variety Seredo) (control): direct planted sorghum.

The experimental treatments were undertaken in January – March 2001, using farmers' crops planted in October 2000.

The participating farmers in Nguuku had been involved in the previous project and were also undertaking their own evaluation of seed sanitation practices. These farmers are now very experienced in farmer-led evaluation. The participating farmers at Kamuwongo and Kiomo had not previously undertaken collaborative on-farm activities.

Second cycle of on-farm (October 2001 – January 2002, March – July 2002)

The 30 participating farmers repeated the experiments of the previous seasons with the inclusion of an an additional treatment:
Treatment 5: (variety Gadam El Hamam) stalks cut at harvest - tillers not thinned.

An additional 20 farmers in Nguuku and Kiomo, plus 10 of the farmers already undertaking on-farm trials in Kamuwongo, voluntered to evaluate suitability of four varieties for ratooning. The varieties evaluated were:

- Seredo,
- Gadan El Hamam,
- Kari mtama 1,
- PGRCE 216740.

Through these activities in Kenya, the present project has both strengthened and expanded the farmer networks through which outputs are generated and promoted.

Output 5: Broadening the cropping base to enhance food security in sorghum cropping systems in Tanzania

Activity 5.1: On-farm evaluation of seed sanitation practices for control of covered kernel smut, Dodoma Rural, Tanzania

Field experiments on control of covered kernel smut in Dodoma Region, Tanzania were conducted to evaluate and promote suitable seed sanitation practices for sustainable control of covered kernel smut of sorghum.

Participatory on-farm experiments were undertaken in Mpalanga, Mloa Barabarani and Msanga. These experiments were managed by members of the farmer groups established at each location. The on-farm work evaluated seed sanitation practices to control covered kernel smut. Each on-farm trial had one replicate plot of each of three treatments. The treatments used were:

Treatment 1 = *lundo* (seed selected using usual farmer practice i.e. seed taken from the harvested sorghum heap)
Treatment 2 = *safi* (seed selected from disease free-heads in the field and removed prior to the main harvest operation)
Treatment 3 = *dawa* (seed treated with thiram based fungicide to control seed-borne fungi).

This work was supported by on-station replications of the same experiments at the Farmer Training Centre, Mloa Barabarani.

The on-farm plots were assessed for covered kernel smut at the end of each season by researchers, extension officers and farmers. A workshop was then held at each location in which the results were presented and pertinent points discussed by the stakeholders.

Initially these experiments provided new information on seed sanitation practices for the control of covered kernel smut. As the projects progressed the plots served for demonstration and learning.

Activity 5.2: Broadening the cropping base to include cassava - variety identification and establishment

The requirement for suitable high quality cassava material, adapted to the local agro-ecological conditions found in Dodoma Rural was addressed by staff of the National Cassava Programme based at SRI, Kibaha. They assisted in the identification and supply of material for the project activities.

Activity 5.3: Farmer adoption of cassava

Farmer groups visited the FTC during year one of the project to see at first hand the establishment and care of cassava. A video was produced of cassava agronomy to act as a learning resource for farmers. This was prepared collaboratively by extension, ZCC, researchers and farmers.

The key to adoption is utilisation. A rapid rural appraisal was undertaken whilst developing the PMF for the present project (R7518) to determine current farmer knowledge on utilisation of cassava in Mpalanga and Mloa Barabarani. A cassava utilisation workshop was subsequently developed, which was specifically ailored to the farmers' requirements. The highlights of this workshop were recorded on video, which has provided an additional learning resource for extension and farmers.

Activity 5.4: Stakeholder workshops to identify suitable sites for community cassava nurseries

These were held concurrently with the stakeholder workshops at the end of the first season (June 1999) for farmer groups participating in the on-farm evaluation of seed sanitation practices for the control of sorghum covered kernel smut (Activity 5.1).

Activity 5.5: Establishment of community cassava nurseries

An area of 0.5 ha was provided by the village authority for cassava multiplication at Mlowa Barabarani and Msanga villages.

OUTPUTS

Output 1: Evaluation of the significance of sorghum smut and potential control options in Uganda

Activity 1.1: Participatory Rural Appraisal

A written report of the findings was distributed at the stakeholder workshop of 21 April 2000 (Appendix 1).

Sorghum Production

Sorghum is grown in both of the principal cropping seasons identified for Teso, Uganda i.e. March – July (first rains) and August – December (second rains). Overall, the farmers interviewed ranked sorghum as the second most important crop grown. Cassava was ranked first in importance and finger millet, groundnuts and cowpeas ranked as third, fourth and fifth respectively. The majority of farmers grow up to 1 acre of sorghum, but some grow up to 3 acres in both seasons. In the second season, some farmers grow from 3-5 acres and a few cultivate in excess of five acres of sorghum.

Sorghum is not used as an industrial crop. All the uses cited were traditional. These included cash, food, brewing, bartering (for food and labour), fuel (stalks), animal feed – particularly for chickens, and mulching for horticultural crops. The desirable characteristics of sorghum were described as high yield (large heads), early maturity, drought tolerance, brown seed (which can be mixed with cassava or millet), good palatability, good brewing qualities, resistance to pests and diseases (including field pests, birds and storage pests), medium height (1.5 m) for ease of harvesting, and ease of processing.

Varieties of sorghum

The majority of farmers in Kumi, Soroti and Pallisa sell some sorghum, only very few farmers reported selling none. In Katakwi, it is mainly grown for food security. The farmers described 20 varieties of sorghum and a further 14 that are no longer cultivated. The reported change in varieties has occurred through both active and passive selection processes. The main active factor that has driven change in variety use (reported by both men and women) is preference for varieties that take less time to mature. A quick maturing variety helps continuity of food supply, increases household cash supply (provided there is surplus of the crop produced) and may escape the negative yield effects of drought.

Seed sources

The majority of farmers save their own seed. Some exchange with neighbours to obtain different varieties or purchase food grain from the market which they use as seed. None of the farmers in Kumi or Katakwi reported using improved seed. One farmer in Pallisa reported the use of improved seed. However, in Soroti district (Odiope village) about one quarter of farmers interviewed used the improved seed variety Sekedo. This was distributed by the Soroti District Development Programme (SDDP). Virtually all farmers use their own home-saved seed for the second season crop. Most farmers bought some seed in most calender years.

Knowledge of smuts

All farmers interviewed (men and women) knew of the existence of smuts, evidenced by seven local names – *ebune, epune, gagigagi, acooli, angwal, aimujuju,* and *ekuna.* Sorghum smut diseases were reported to be increasing. Farmers in Kumi and Pallisa reported losses from 50 – 100 %. Farmers in Opiriai village, Katakwi reported 100%. Losses reported elsewhere were lower – Soroti village 25 %, Katakwi, Aparisia vilage, 10 %; and Kaberamaido village 10 %. A minority of farmers reported taking seed from the field prior to harvest and putting this aside for the next season crop. The majority of farmers obtain seed from the main harvested crop either as heads from the harvested heap or after threshing. This practice facilitates spread of covered kernel smut spores. Additionally, farmers reported that very badly smutted heads were often left on the field for subsequent burning. This practice could pre-dispose the subsequent crop to long smut.

Activity 1.2: Disease survey

The report of this activity may be found in Appendix 2.

Sorghum smuts and, in particular, covered kernel smut were frequently observed in Ugandan fields (Table 4). The highest occurrence of covered kernel smut (93.3 % of sorghum plants affected) was observed in Kumi district. The lowest occurrence was in Soroti district (25.6 % of sorghum plants affected).

The occurrence of *Striga* spp. within the fields was high, *Striga hermonthica* occurring more frequently than *Striga asiatica* (Table 5). The occurrence of *Striga hermonthica* in Soroti, Kumi, and Pallisa Districts was 38.5, 78.3 and 75.4 % respectively, while the occurrence of *Striga asiatica* in Soroti, Kumi, and Pallisa districts was 10.5, 40.0 and 45.9 % respectively.

The variation in the mean incidence of covered kernel smut in the fields assessed in each of the four districts varied considerably ($p<0.001$). The range varied from 2.5% in Sorti to 22.5% in Katakwi . The incidence of covered kernel smut in the four districts was significantly different ($p<0.05$). The variation in the mean severity of covered kernel smut in the fields assessed in each of the four districts was significant ($p<0.001$). The greatest severity of CKS i.e. grain loss, was highest in Katakwi district with 43.0% and lowest in Soroti with 1.3%.

Table 4: Incidence of sorghum smuts in Teso, Uganda (July 2000)

District	Number of fields assessed	CKS	Head smut	Loose smut
			% incidence	
Soroti	39	25.6	10.5	5.1
Kumi	60	93.3	40.0	10.0
Pallisa	61	55.7	45.9	21.3
Katakwi	30	96.7	6.7	20.0
Total	190			

Note: CKS = covered kernel smut of sorghum

Table 5: Incidence of *Striga* spp. in Teso, Uganda (July 2000)

District	Number of fields assessed	*Striga hermonthica* % incidence	*Striga asiatica* % incidence
Soroti	39	38.5	10.5
Kumi	60	78.3	40.0
Pallisa	61	75.4	45.9
Total	140		

The principal source of covered kernel smut is from contaminated seed. The fungus spreads systemically during the growth of the plant, finally infecting the developing panicle, replacing the grain with smut sori. When the sori burst, the teliospores may be blown to other sorghum panicles. As a consequence, there is the potential for limited development of smut through cross-contamination at that stage. However, the infection arising through seed-borne inoculum is the most severe. The similarity of the trends between incidence and severity is therefore as expected for a seed-borne fungus of this nature. The lower incidence of diseases in Soroti district may well be a consequence of the diffusion of knowledge, seed and other inputs to growers who benefit from close proximity to the research station.

Overall, the most common cropping system for sorghum was intercropping with finger millet (43.7), followed by pure stand (37.4) and groundnuts (12.6%) (Table 6). Only in Katakwi district was it more common to plant pure stand sorghum crops than sorghum and finger millet intercrop.

During the survey, 83 different sorghum variety combinations were identified. The most common varieties were Edeidei and Nakasuta which occurred in 15.7 % and 1.9 % of the fields assessed. The variety Edeidei was grown mainly in Soroti and Katakwi districts and the variety Nakasuta in Pallisa Ddstrict. The majority of the farmers (64 %) grew only one variety of sorghum in their fields (Table 7). There were no significant disease effects observed due to mixtures vs pure stands.

Table 6: The occurrence of the different cropping systems in Teso, Uganda (July 2000)

Cropping system	Number of fields in each district with cropping system (%)				Total number of fields	Total % fields with cropping system
	Soroti	Kumi	Pallisa	Katakwi		
Pure stand	12 (30.8)	15 (25.0)	25 (41.0)	19 (63.3)	71	37.4
Finger millet[1]	23 (59.0)	22 (36.7)	31 (50.8)	7 (23.3)	83	43.7
Groundnuts	3	19 (31.7)	0	2	24	12.6
Cassava	0	3	2	0	5	2.6
Simsim	1	0	0	1	2	1.1
Maize	0	0	2	0	2	1.1
Trees	0	1	0	0	1	0.5
Sesame	0	0	1	0	1	0.5
Green grams	0	0	0	1	1	0.5
Total	39	60	61	30	190	

[1] sorghum crop intercropped with….
Figures in brackets represent percentages

Table 7: The frequency of usage of pure stands or variety mixtures Teso, Uganda (July 20000

Number of varieties in field	Fields in each district with different sorghum mixes (%)				Total number of fields	Total % fields
	Soroti	Kumi	Pallisa	Katakwi		
Pure stand	17 (43.6)	27 (46.5)	47 (88.7)	27 (90.0)	118	63.8
2 varieties	16 (41.0)	22 (37.9)	8 (15.1)	3 (10.0)	49	26.5
3 varieties	6 (15.4)	9 (15.5)	3 (5.2)	0	18	9.7
Total	39	58	58	30	185	

Figures in brackets represent percentages

The disease survey was used to quantify the frequency of different seed sources (initially listed in the PRA) and to relate seed source to disease incidence. These data are shown in Table 8. The PRA revealed only limited appreciation of the significance of seed-borne inoculum by farmers. There was a correspondingly low frequency of seed sanitation (4 %) through saving and selecting disease-free seed. Collectively, 85 % of seed used to produce the crops surveyed had been obtained from either home-saved seed or seed bought in the market. Thus there was a potentially high likelihood of significant spread of seed-borne covered kernel smut. This was reflected in the incidence and severity of disease on sorghum established using seed from these sources. The incidence and severity of covered kernel smut was correspondingly low where seed had been selected to avoid contamination with covered kernel smut or where seed was purchased from SAARI, Serere.

Table 8: The effect of seed source on the incidence and severity of covered kernel smut in Teso, Uganda (July 2000)

Seed source	% of household using seed source	Mean incidence of CKS (%)	Mean severity of CKS (%)	Number of fields surveyed
Saved from previous crop	38.7	9.0	7.5	67
Selected by farmer	4.0	1.3	1.1	7
Obtain from a neighbour	9.8	9.3	7.3	17
Bought from market	46.2	11.6	13.4	80
Obtained from Serere	1.2	0.0	0.0	2
Total		9.8		173

The detailed report and analysis of this activity is presented in Appendix 2

Activity 1.3: Stakeholder workshop

The stakeholder workshop enabled development of an agreed action plan, commencing with the disease survey that was scheduled for the end of the March-July 2000 cropping season.

Stakeholders considered the need to reduce sorghum grain losses in the field as a priority. Covered kernel smut appeared to be a major cause of these losses (and this was subsequently confirmed in the disease survey undertaken later that growing season). The farmers and NGOs emphasised the need for information of project findings to be made available to the Teso communities.

Activity 1.4: Feed-back to communities through village / farmer meetings

Four farmer groups were established in Kumi and Pallisa. In conjunction with the extension service and SAARI/NRI, on-farm experiments were established to serve as validation / learning plots for seed sanitation practices. The establishment of the on-farm experiments resulted in regular contact between farmers, research and extension throughout the second and third year of the project. As a consequence, members of the farmer groups were updated on the results of the disease survey and the ongoing work based at SAARI in support of project activities. The points arising from their feed-back were documented and, where appropriate, integrated into the on-going project.

Activity 1.5: On-station experiments undertaken at SAARI, Serere

Where sorghum crops were grown from seed which was treated with thiram each season (T3, T6, T9 & T12) complete control of covered kernel smut was achieved over three seasons. This result was expected and was shown to be independent of variety or the initial level of seed-borne inoculum. (Table 9).

When treated seed was replanted for a second season, it's disease-free status was maintained irrespective of variety (T2, T5, T8 & T11). However, this protection was not effective for a third season for sorghum cv. Eyera which showed a high disease incidence (T8 = 50 %, T11=42 %). In contrast, sorghum cv. Enyang remained effectively disease free (T3 & T5).

The red cv. Eyera is particularly loose-headed and observations in Kenya and elsewhere have shown that the loose head favours spread of covered kernel smut between plants. It is likely that the inoculum present in the second season in cv. Eyera T8 & T11 dispersed within the plots of this treatment resulting in a much higher observed incidence of covered kernel smut in the third season. The more compact nature of cv. Enyang was less favourable to dispersal of spores between heads, thus control of covered kernel smut was retained in the third season crops.

Table 9: The effect of variety and disease pressure on the efficacy of fungicide seed treatment for the control of sorghum covered kernel smut.

	Seed stock	Variety	Colour	Initial Disease Status	Seed Treatment 1	2	3	Season No. 1	2	3	4
1	A	Enyang	White	Low	N	N	N	43	22	57	
2	A		White	Low	Y	N	N	0	2	0	
3	A		White	Low	Y	Y	Y	0.2	0	0	
4	B		White	High	N	N	N	66	50	59	
5	B		White	High	Y	N	N	0.2	4	0	
6	B		White	High	Y	Y	Y	0.1	0	0	
7	C	Eyera	Red	Low	N	N	N	2.1	15	44	
8	C		Red	Low	Y	N	N	0.2	2	50	
9	C		Red	Low	Y	Y	Y	0	0	0	
10	D		Red	High	N	N	N	2.9	8	38	
11	D		Red	High	Y	N	N	0	1	42	
12	D		Red	High	Y	Y	Y	0	0	0	
Lsd ($p < 0.05$)								1.52	7.39	17.5	

Output 2: Identification of varietal resistance to smut and pathogen variability in Uganda

Activity 2.1: Screening for varietal resistance to covered kernel smut

The establishment of all (185) lines of sorghum was very poor. This was due to severe drought during the emergence period and poor quality seed. The activity was repeated in year three of the project using ten main breeding lines identified by staff of SAARI. The disease incidence and severity data are presented in Table 11. The variety Epuripur which is presently in demand from a Ugandan commercial brewery appears highly susceptible to covered kernel smut. The farmer variety Enyang appeared considerably less susceptible to covered kernel smut than Epuripur, but was more susceptible than the farmer variety Eyera. Examination of the incidence of covered kernel smut on these two varieties on farmers fields (Table 12) shows that Enyang had a very high incidence of covered kernel smut (19.3 %) compared to Eyera (8.7 %). Some of the lines such as BD 31/9/1 showed a promisingly high level of resistance.

Table 10: Incidence and severity of covered kernel smut on ten varieties of sorghum grown from disease-free seed (Data from Kumi field site, August 2002)

Treatment number	Sorghum variety name	Disease status of seed	Severity	Incidence	Disease product
1	Enyang	-	0	0	0
3	Sekedo	-	33.3	7.3	243.1
5	ANI/7/1/2	-	0	0	0
7	Epuripur	-	0	0	0
9	LDRM 11/1/1/1/	-	0	0	0
11	IS 8193	-	0	0	0
13	Eyera	-	0	0	0
15	BD 31/9/1	-	0	0	0
17	IS21005	-	0	2.4	0
19	4M x 11/8	-	0	0	0

Note: - = disease-free seed

Table 11: Incidence and severity of covered kernel smut on ten varieties of sorghum grown from inoculated seed (Data from Kumi field site, August 2002)

Treatment number	Sorghum variety name	Disease status of seed	Severity	Incidence	Disease product
2	Enyang	+	38.2	24.5	935.9
4	Sekedo	+	66.3	36.9	2442.7
6	AN1/7/1/2	+	48.3	49.9	2 410
8	Epuripur	+	53.3	46.9	4 999.5
10	LDRM 11/1/1/1	+	62.5	50.5	3 125
12	IS 8193	+	52.5	21.8	1 144.5
14	Eyera	+	41.7	11.8	492.06
16	BD 31/9/1	+	0	0	0
18	IS21005	+	0	0	0
20	4M x 11/8	+	55.4	34.99	34.99

Table 12: Incidence of covered kernel smut on eight most frequently grown varieties in Teso, Uganda (Data from July 2000 disease survey)

Sorghum name	Number of surveyed fields	Observed CKS incidence (%)	Transformed data		Back-transformed data	
			Prediction	s.e	Prediction (%)	95% cl
Edeidei	13	11.2	-2.075	0.307	11.2	(6.4, 18.7)
Serena	6	10.3	-2.161	0.467	10.3	(4.4, 22.4)
Enyanga	9	19.3	-1.428	0.294	19.3	(11.9, 29.9)
Sekedo	5	6.1	-2.727	0.648	6.1	(1.8, 18.9)
Eiyera	6	8.7	-2.355	0.506	8.7	(3.4, 20.4)
Ekoli	5	6.0	-2.752	0.656	6.0	(1.7, 18.8)
Enakasuta	14	3.9	-3.216	0.484	3.9	(1.5, 9.4)
Elemureng	14	21.7	-1.282	0.320	21.7	(12.9, 34.2)

Activity 2.2: Evaluation of the pathogenicity of a range of CKS isolates to a range of sorghum cultivars

The intention in this activity was to select promising resistant lines from activity 2.1 and determine the genetic variability of this germplasm to isolates of *S. sorghi* isolated during the July 2000 disease survey during.

This activity could not be undertaken. Dr Esele, who had particularly requested inclusion of activity 2.2 in the project, was elected as MP for Kumi District and therefore had to resign his post at SAARI. Mr J P Takan who had been working closely with Dr Esele in support of the project and would have undertaken the screening activities was seconded shortly afterwards to the UK on another CPP-funded project. The situation was discussed with Dr J Oryokot (then Director of SAARI) and Dr B Akello (who assumed Mr Takan's role on the project). As the project had progressed, it had become clear that there was a need to link SAARI activities with the priorities of Teso communities through more effective promotion and dissemination of information on the control of covered kernel smut. This demand was voiced in the initial stakeholders workshop (Activity 2.3).

The former CPP Manager, Dr Eden-Green and the DFID advisor Dr D Kisauzi visited the activities at Serere (13 February 2001); during that visit the importance of including, on-farm work if at all possible, was emphasized. Additionally, extension providers themselves had expressed a need for dissemination of information when project staff visited their offices during activities 1.1 and 1.2. It was therefore concluded that as the staff identified in the PMF were no longer in post, activity 2.2 could not be undertaken. However, resources could be redirected towards an additional on-farm output, which would add value by providing an opportunity for promotion and dissemination to the intended beneficiaries of the project.

Output 3: Promotion and dissemination of developed control strategies for CKS in Kenya and Tanzania

Activity 3.1: Promotion of control strategies for covered kernel smut in Kenya

On-farm activities

In support of the East Africa Food Security Programme, FAO are presently funding a farmer field school initiative in Mwingi District. This involves collaboration between GTZ and the District Extension Service in Mwingi. It reaches at least two farmer field schools in each of seven divisions. The extension officers that have received training on the sustainable control of sorghum covered kernel smut through the CPP sorghum smut activities have incorporated the knowledge of suitable seed sanitation practices into this Programme.

District extension staff also reviewed the project booklet on the identification and control of smut (presently being distributed in Tanzania). This booklet is written in Tanzanian Kiswahili. The extension officers considered that it provides clear coverage of the identification of sorghum smut diseases and their control. They requested that this booklet is revised and reproduced for distribution in Kenya, suggesting that both an English language and a Kenyan Kiswahili version would be appropriate.

Access to the next generation (inter-schools drama competitions)

A video record of the competition was made. Highlights from three of the plays, which were conducted in the local language Kikamba, have been produced with English subtitles. This initial dissemination output has been lodged with KARI and copies are included with this FTR. It is proposed that the complete footage can be further edited and formatted to enable distribution of this promotional output to provide a resource for the District Education Services, Extension Officers and, of course, the schools in those locations.

Impact assessment of inter-schools drama competitions

In the focussed group discussion with farmers from Katse and Kiomo, highly positive and immediate feed-back served to endorse the activity. The audience had received new knowledge on the identification, biology and control of covered kernel smut. They considered that the nature of the event and the humour incorporated into the plays enhanced the learning process. The timing of the drama competition – shortly before harvest – allowed for the extension message of selection of disease-free sorghum seed to be implemented in that season.

Discussions with the school children revealed that they now felt confident and could potentially assist their parents in the identification and management of covered kernel smut. All pupils found the drama competition an interesting and enjoyable inclusion within the school curriculum.

In the questionaires returned from agriculture and extension officials, it was apparent that role play was viewed as an effective channel for dissemination of the extension message on seed sanitation practices for control of sorghum covered kernel smut. Respondents emphasised that children passed on the new knowledge to members of the audience and other home contacts.

The socio-economic report of this assesment may be found in Appendix 3.

Activity 3.2 Promotion of control strategies for covered kernel smut in Tanzania

Identification of the school partnership

Covered kernel smut of sorghum is highly visible and is easy to identify once a degree of familiarity with the appearance of the disease is achieved. The seed sanitation practices required to control this seed-borne disease (clean-seed selection or fungicide seed treatment) are straightforward provided that adequate training and information is provided. The effect of these treatments is highly visible in the field. These characteristics ensure that the "control message" can be readily understood when conveyed to primary school children through trained teaching professionals. The control message is therefore appropriate for dissemination through schools and the proposed activities involving teaching professionals were endorsed by the agriculture and education officials consulted.

The participating schools were chosen by the DEDO and extension services. They were all in locations with significant sorghum production and disease pressure. This ensured that the specific message of control of covered kernel smut was relevant to the communities served by the schools. School participation was by invitation and the teaching professionals were free to accept or decline the invitation. Participating teachers could choose how much of their time they devoted to the schools-centred activities and they were also free to discontinue their involvement with the initiative at any time.

Training and development of an action plan (First teachers' workshop)

The training day held at the Farmer Training Centre, Bihawana (FTC) on June 24th 2000 was highly successful. Teachers were briefed on the life cycle and control options for covered kernel smut and the field trials at the FTC (undertaken in support of R7518) were used as a practical demonstration of covered kernel smut symptoms on sorghum. Data from the on-farm trials was used to demonstrate the level of control that could be achieved. Practical observations involved individual contact between extension staff (trained under the previous phase R6581) and teachers. The day concluded with group discussions on the manner in which the teachers could incorporate this information into their school curriculum. The teachers agreed that they would use the new knowledge gained on control of covered kernel smut during the next academic year. They would then have a "moving forward" workshop to compare methods and experiences and to decide on how to proceed further. The date was agreed for the follow-on workshop. Teachers wishing to participate in that workshop were requested to forward a letter briefly outlining their activities prior to the "moving forward workshop".

Moving forward (Second teachers' workshop)

The report of this workshop may be found in Appendix 4.

All teachers gave a highly positive account of their experiences of incorporating awareness of sorghum smut and its control into their curriculum. Nineteen different teaching methods were described which included lecturing, use of real objects in classroom situation, drama and field experimentation. These activities and the number of teachers who reported employing them are listed in Table 13 (Page 35). The two most commonly used methods were school experimental plots (reported by 11 teachers) and teaching through music and songs (reported by 8 teachers). All teachers used more than one method (Table 14).

Table 14: Frequency distribution of various teaching methods for smut awareness and control

Number of teaching methods	Frequency of use
1	0
2	3
3	3
4	3
5	5
6	1
7	1

Seminar participants evaluated the *pros* and *cons* of the methods used (Table 15). They then ranked the different methods in terms of usefulness (Table 16). Teaching using "real things" to illustrate concepts was considered most useful in the daily situation (Table 17).

Table 13: Activities used by teachers in Dodoma Rural to incorporate awareness of sorghum smut and its control into their curriculum, academic year 2000/01

Activity	Description / target group	Number of teachers using the activity
Seminars	for teachers	6
	for parents	3
	for pupils	4
	for women's group	1
	for village government	7
	for village residents	3
Farm visits	Pupil and teacher --> farm	4
	Teacher --> farm	2
Field experiments	Sorghum grown with different seed sanitation practices	11
Student teaching	Music / songs	8
	Poems	4
	Drama	2
	Lecturing	6
	Real things (pupils bring infected sorghum from home)	1
Parents	Parents visit school experimental plots	1
Discussion	School committee	1
	Parents day	1
	Village livestock day	1

Table 15: Evaluation of different methods for incorporating information on covered kernel smut into teaching activities

Method	*Pros*	*Cons*
Kutumia vitu halisi (real things)	Best for all age groups Suitable for both male and female Appropriate for range and ability of educational levels encountered Suitable for all cultures	Seasonal i.e. depends on availability of subject matter in relation to school year
Nadharia (theoretical)	Good for children from 5 years old Suitable for boys and girls Particularly good for higher educational levels and abilities Not affected by culture not dependent on seasonality	May be too didactic
Mashamba ya majaribio (experimental plots)	Suitable for students and farmers spanning a wide age range (up to 50 +) Suitable for both male and female A valuable teaching / learning tool for all levels of education and ability |No cultural constraints	Not necessarily suitable for very young children Influenced by time, environment and seasonality
Kuelimisha kwa nyimbo mashairi na ngonjera (learning through songs, poems and drama)	Suitable for all age groups Suitable for both male and female Suitable across the range of educational levels Applicable to all cultural groups Not affected by "mood" (?) Some independence of seasonality	
Kuchagua mbegu (seed selection)	Educational level not necessarily a constraint Suitable for both male and female	Seasonal Not appropriate for teaching to the very young or the very old

Table 16. Teachers' ranking of usefulness of different teaching methods

Teaching method	Ranking	
	Usefulness	Resource demand
Kutumice vitu halisi (use real things)	1	2
Nadharia (theoretical)	2	4
Mashamba ya majaribio (experimental plots)	3	5
Kuelimisha kwa nyimbo mashairi na ngonjera (learning through songs, poems and drama)	4	3
Kuchagua mbegu (seed selection)	5	1

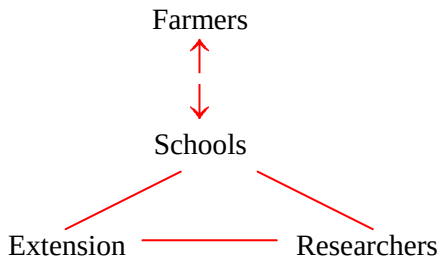
Note 1-5 scale where 1 is the highest

In terms of resources, seed selection was rated as cheapest whereas experimental plots was the most demanding of the methods in relation to inputs including time and resources.

The account of activities undertaken by teachers showed that they had effectively incorporated information on the biology and control of covered kernel smut of sorghum into their teaching programmes. The presentations and discussions of Day 1 of the seminar showed the value of linkages between teachers, extension and researchers in the promotion of information. The convergence of the roles of extension officers and teaching staff in dissemination was highlighted. There exists a triangle of interaction between schools, researchers and extension services in the dissemination of knowledge on the control of covered kernel smut of sorghum (Fig 1).

Figure 1: Dissemination triangle

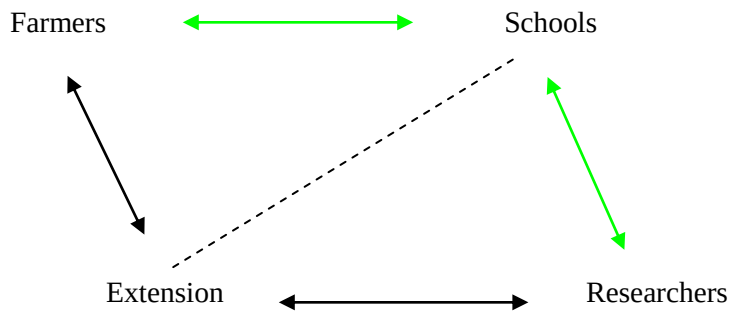
<u>*Bridging the gap*</u>



The strength of this dissemination triangle depends on the targeting of resources and ensuring strong linkages. This triangle was the focus of the activities of Day 2 of the seminar. On the first day the emphasis was essentially on the teachers' activities. On the second day, the views and experiences of researchers and extension officers were sought as well as those of the teachers. The resources and linkages necessary to sustain this triangle were considered. There was a general concensus that effective promotion of sustainable control of covered kernel smut involved inputs from several tiers of stakeholders. These include Ministry, local government researchers, extension, farmers and teachers. This process of engagement has so far been successful. It was felt that the project had successfully utilized strong research – extension – farmer linkages and that new linkages had been developed between researchers – schools – farmers. During the workshop, the requirement to strengthen the extension – schools linkage was identified.

Fig 3: The Promotion Parallelogram

Possible Solution?



Key:
___ = linkages established and used during project
___ = new linkages being developed within project
----- = linkage identified for strengthening

The seminar participants identified documentation of their successes i.e. the methods by which they had successfully incorporated knowledge of the identification and control of covered kernel smut of sorghum into their professional teaching activities, as a priority. It was agreed that documentation should be through reports, pictures and videos. The documentation was started in October 2001, with production of both a video and a written report of the workshop. Documentation of a logical progression of teaching activities over the course of a sorghum season from planting (October / November 2001) to harvest (May / June 2002) was jointly undertaken by the groups. Schools in each division were visited and some aspect of activities documented by the project partners.

Documentation and promotion of schools activities in Tanzania.

1. A video has been produced of the second teachers' workshop. Copies of this video have been deposited with the Zonal Communication Centre and are available as a training and information resource to FTC, Bihawana, Dodoma Extension, Dodoma Education Office and Research Institutes.
2. The written proceedings of the second teachers' workshop (Appendix 4) were distributed to project partners, CPP, Ministry of Agriculture and Food Security, DEDO, participating teachers and extension officers. They were also distributed more widely to extension and agriculture officials in Dodoma Rural, Singida and Mpawpwe. To date, 115 copies have been distributed to stakeholders.
3. A video has been produced of a range of activities including song, wrap, dance and field experimentation at Msanga Primary School. Copies of this video have been deposited with the Zonal Communication Centre and are available as a training and information resource to FTC, Bihawana, Dodoma Extension, Dodoma Education Office and Research Institutes. This video was also transferred to CD and was effectively used to illustrate activities during planning discussions with government officials. Copies of this CD were forwarded to CPP in July 2002).
4. Staff from Msanga School and Wilunze School attended a project conclusion workshop in Dodoma (14 August 2002) and presented accounts of their activities to the stakeholders. These are summarised in the written output from that meeting (Appendix 8).
5. All participating schools effectively incorporated knowledge of sorghum smut into their curriculum. Awareness was raised within the school and local communities by demonstrations to parents and farmers of songs, dance etc. at graduation days. Furthermore, two schools held specific farmer days for inspection of on-school trials. Activities on the identification and control of sorghum smut were highlighted within schools by various means. These included school assembly and football competitions where teams were named after key aspects of the extension message e.g. "*mangwilili*" (local term for sorghum smut).
6. The project booklet written in Kiswahili on the identification and control of sorghum smuts and striga (Appendix 10) was distributed to participating teachers. At the request of the DEDO, additional copies of this booklet were provided. These were distributed to 150 schools in Dodoma Rural.

Evaluation of schools activities

Considerable baseline data has been generated by the project through the outputs listed above. Schools are clearly an excellent pathway for dissemination of appropriate information such as the covered kernel smut control message. However, education is an important issue as is the status of children. Also, the extension service has an important role to play in assisting farmers to adopt new ideas and technologies. At each stage of the activities reported here, the relevant authorities were consulted. Throughout the documented activities, stakeholders identified a range of strengths, weaknesses, opportunities and threats to successful engagement with schools and extension in the promotion and dissemination of agricultural knowledge. These are summarised in Table 17.

Table 17: Evaluation of extension schools partnerships for dissemination of agricultural information

	Schools	Extension
Strengths	• Teachers reach individuals outside of the demarcated school environment • Teachers view extension from classroom to community as a significant part of their professional roles • Agricultural education is valued by both the Ministry of Agriculture and Education	• Agricultural education is valued by both the Ministry of Agriculture and Education • Extension officers are a service provided specifically to assist farmers • Benefit from established linkages with researchers providing opportunities for "technical updating"
Weaknesses		• Extension officers clients (farmers) are spatially disparate • Extension officers deal with individuals or small groups of farmers on a range of issues • Extension often lack infrastructure especially transport • Extension officers are not "professional" trainers • Low manpower; there is a maximum of one extension officer per village and, often, less
Opportunities	• Convergence of the role of teachers and extension officers in promoting the knowledge gained through research to those who are involved in crop production • Farmers and teachers work together because teachers have a prominent role locally • Teachers are professional trainers • Teachers have contact	• Convergence of the role of teachers and extension officers in promoting the knowledge gained through research to those who are involved in crop production

	with adult farmers through their link with children. Farmers therefore hold teachers in esteem and are receptive to them as reliable and useful sources of information • Schools lie at the heart of the community. Each village usually has 5 teachers • A large number of pupils come to the schools daily. The communication between teacher and pupil benefits from a large number of conduits	
Threats	• Inputs and resources for training teachers needs to be maintained to ensure high quality and relevant incorporation of subject matter into the curriculum • Schools must not be "overloaded". Important that only relevant and appropriate material is incorporated into the curriculum • Schools are first and foremost for education. Agricultural activities there should primarily focus on education. They should be complimentary to, rather than a substitute for, extension and farmer group activities	• Extension is important and schools activities should compliment these and not compete for resources

Working with schools is an exciting and rewarding activity. The successes and experiences in the project reported here indicate that the processes and subject matter can be transferred to other areas of Central Zone Tanzania e.g. Syngida. Also the process could be adapted for other suitable messages. However, the material used and the manner in which the processes described here are adapted for use in other zones or other countries warrants careful consideration.

Output 4: Evaluation of sorghum ratooning for enhancement of food security in Kenya

Activity 4.1: Comparison of sorghum ratooning and direct sowing in relation to incidence of pests and diseases

Short rains October 1999 – February 2000

Incidence of covered kernel smut

The incidence and severity of covered kernel smut (Tables 18 & 19) was significantly affected by the application of those treatments including thiram applied as a fungicide seed dressing ($p<0.001$). Two treatments, T3 & 4 and T9 & 10, significantly ($p<0.05$) reduced the incidence of covered kernel smut (Tables 18 & 19). The predicted incidence of covered kernel smut in the treatment which did not incorporate a CKS control element (T1 & T2) was 39.9 % compared to 11.1 % for the fungicide seed treatments (T3 & T4) and 7.5% for the blanket protection treatments (T9 & T10). The predicted severity of covered kernel smut in the nil control treatment (T1 & T2) was 29.3 % compared with 8.5 % on the crops grown from fungicide treated seed (T3 & T4) and 4.6 % on crops grown under the blanket protection treatment (T9 & T10).

Table 18: The effect of fungicide seed treatment on the incidence (%) of covered kernel smut (KARI, Katumani, short rains 1999)

Treatments	Observed incidence (%)	Transformed data		Back-transformed data	
		Prediction	s.e	Prediction (%)	95% cl
T1 & T2	36.8	-0.409	0.253	39.9	(28.8, 52.2)[2]
T3 & T4	11.3	-2.079	0.360	11.1	(5.8, 20.2)[1]
T5 & T6	30.9	-1.005	0.271	26.8	(17.7, 38.3)[2]
T7 & T8	30.2	-0.854	0.248	29.9	(20.8, 40.9)[2]
T9 & T10	8.7	-2.520	0.444	7.5	(3.3, 16.1)[1]

Key [1] = significantly different (p = 0.05) from the nil control treatment (T1 & T2)
[2] = significantly different (p = 0.05) from the blanket protection treatment (T9 & T10)

Table 19: The effect of fungicide seed treatment on the severity of covered kernel smut (KARI, Katumani, short rains 1999)

Treatments	Observed	Transformed data		Back-transformed data	
	severity (%)	Prediction	s.e	Prediction (%)	95% cl
T1 & T2	27.6	-0.879	0.218	29.3	(21.3, 38.9)[2, 3]
T3 & T4	8.1	-2.381	0.328	8.5	(4.6, 15.0)[1]
T5 & T6	21.2	-1.462	0.242	18.8	(12.6, 27.1)[2]
T7 & T8	20.7	-1.379	0.221	20.1	(14.0, 28.0)[2]
T9 & T10	5.5	-3.045	0.427	4.6	(2.0, 9.9)[1]

Key [1] = significantly different (p = 0.05) from nil control treatment (T1 & T2)
[2] = significantly different (p = 0.05) from blanket protection treatment (T9 & T10)
[3] = significantly different (p = 0.05) from fungicide seed dressing treatment (T3 & T4)

Incidence of stem borers

There was a large number of plants showing symptoms of stem borer damage at the 5-7 leaf stage for all treatments. Although there appeared to be differences between the damage levels for the different pest control combinations under investigation, these differences were not, in fact, statistically significant (Table 20). The accumulated analysis of deviance for treatments was 0.075 and for position in the field 0.674. The lowest predicted incidence was under the blanket protection treatment (T9 & T10) at 84.5%, followed by those crops which had been treated only with the stem borer control product Buldock i.e. T5 & T6 (91.1%). However, the level of foliar damage caused by stem borers at the 5-7 leaf stage was significantly higher (p = 0.012) in the nil control treatments (T1 & T2) than in the blanket protection treatment (T9 & T10).

Table 20: The effect of control treatments on the incidence of stem borer damage on sorghum at the 5-7 leaf stage (KARI, Katumani, short rains 1999)

Treatments	Observed	Transformed data		Back-transformed data	
	incidence (%)	Prediction	s.e	Prediction (%)	95% cl
T1 & T2	95.0	3.024	0.654	95.4	(85.1, 98.7)
T3 & T4	96.3	3.442	0.777	96.9	(87.2, 99.3)
T5 & T6	91.3	2.335	0.552	91.2	(77.8, 96.8)
T7 & T8	98.3	3.995	1.023	98.2	(88.0, 99.8)
T9 & T10	83.3	1.696	0.468	84.5	(68.6, 93.2)

Table 21: Frequency of stem borer foliar damage scores (KARI, Katumani, short rains 1999)

Treatment	Stem borer damage (frequency) Damage grade*				Total
	1	2	3	4	
Nil control treatments[1] (T1 & 2)	1	222	91	6	320
Blanket protection treatments[1] (T9 & 10)	1	255	62	2	320
Total	2	477	153	8	

NOTE:

[1] Pearson chi-square asymptotic significance (2 sided) = 0.021[a]
[1] Monte Carlo significance (2 sided) =0.012[b] with 95% confidence intervals of 0.010 and 0.014
[a] 4 cells (50%) have expected counts less than 5. The minimum count is 1.00
[b] based on 1000 sampled tables with starting seed 2,000,000

*Damage grades
1 = no symptoms of damage
2 = few pin holes and shot holes (small holes) on a few leaves
3 = several shot holes on a few (<50%) leaves
4 = several (>50%) leaves with several shot holes or small lesions (<2 cm long)

There were no consistent trends relating incidence of stem borers as assessed by mean tunnel length per stem and mean number of larvae found per dissected stem at crop maturity. There was some indication that stem borer effects were less on those crops treated with Buldock (especially T7 & T8) (Table 22 & 23).

Table 22: The effect of control treatments on mean stem borer tunnel length (cm) per stem (Katumani, short rains 1999)

Treatments	Observed length (cm)	Unbalanced data		
		Prediction	s.e	95% cl
T1 & T2	2.1	1.8	0.5	(0.8, 2.8)
T3 & T4	3.4	3.8	0.5	(2.8, 4.9)
T5 & T6	1.4	1.6	0.5	(0.5, 2.6)[3]
T7 & T8	1.3	0.7	0.5	(0, 1.7)[3]
T9 & T10	2.4	2.7	0.5	(1.6, 3.8)

Key: [3] = significantly different ($p \leq 0.05$) from fungicide seed dressing (T3 & T4)

Table 23: The effect of control treatments on the mean number of stem borer larvae per stem per treatment (KARI, Katumani, short rains 1999)

Treatment	Observed numbers	Unbalanced data		
		Prediction	s.e	95% cl
T1 & T2	0.2	0.2	0.04	(0.1, 0.2)
T3 & T4	0.2	0.3	0.04	(0.2, 0.3)
T5 & T6	0.2	0.1	0.04	(0.0, 0.2)
T7 & T8	0.1	0.1	0.04	(0, 0.2)
T9 & T10	0.2	0.2	0.04	(0.1, 0.3)

Long rains March – July 2000

Incidence of covered kernel smut

In the second season, commencing March 2000, half of the plots contained sorghum crops established from seed (i.e. not ratooned), while the other half contained sorghum crops that had been ratooned after the harvest at the end of short rains season. The poor rains received during the long rains season of March – July 2000 resulted in low establishment and poor development of the direct sown sorghum crop. The direct seeded crop did not reach maturity. This is a clear indication of the potential value of ratooning practices to small holder sorghum growers. The data sets obtained were analysed for the effectiveness of control methods and differences between short rain and long rain crops.

Data on the incidence and severity of covered kernel smut are summarised in Table 24 and 25. The treatment to control covered kernel smut involves a fungicide seed treatment that could, obviously, not be applied to the ratooned crop. The incidence of covered kernel smut in the ratooned sorghum grown during the long rains was significantly related to that found previously in the short rains crop (incidence $p < 0.001$, severity $p = 0.011$). The highest predicted incidence of covered kernel smut was for the treatment which did not include a CKS control element (T2 = 34.3 %). The lowest was for blanket protection treatment (T10 = 10.2%). The actual incidences were 47.7% for T2 and 6.8% for T10. The relationship between the incidence of CKS in the short rains and long rains was highly correlated with the trendline accounting for 79.3% of the variation in the data (Figure 3). The slope of the line indicates that there is a positive correlation, with the levels higher in the long rains compared to the short rains (Figure 4). The predicted severity of covered kernel smut in the nil treatment (T2) is the highest (31.3%) and the predicted severity in the blanket protection treatment (T10) is the lowest (4.4%). The severity of covered kernel smut is less correlated with the trendline accounting for 51.9% of the variation. The observed incidence and severity of covered kernel smut were not affected by the application of insecticide (incidence $p = 0.245$ and severity $p = 0.155$).

Table 24: The effect of fungicide seed treatment on the incidence of covered kernel smut on the ratooned crop (KARI, Katumani on-station trial, long rains 2000)

Treatments	Observed incidence (%)	Transformed data		Back-transformed data	
		Prediction	s.e	Prediction (%)	95% cl
T2	47.7	-0.651	0.367	34.3	(20.3, 51.7)
T4	19.0	-1.100	0.350	25.0	(14.3, 39.8)
T6	31.2	-1.349	0.335	20.6	(11.9, 33.4)
T8	41.0	-0.661	0.276	34.1	(23.1, 47.0)
T10	6.8	-2.180	0.569	10.2	(3.6, 25.6)

Table 25: The effect of fungicide seed treatment on the severity of covered kernel smut on the ratooned crop (KARI, Katumani on-station trial, long rains 2000)

Treatments	Observed severity (%)	Transformed data		Back-transformed data	
		Prediction	s.e	Prediction (%)	95% cl
T2	34.6	-0.785	0.458	31.3	(15.7, 52.8)
T4	13.6	-1.706	0.422	15.4	(7.4, 29.4)
T6	21.7	-1.457	0.382	18.9	(9.9, 33.0)
T8	29.0	-0.938	0.315	28.1	(17.4, 42.1)[1]
T10	4.3	-3.097	0.716	4.4	(1.1, 15.8)

Key: [1] = significantly different (p = 0.05) from blanket protection treatment (T10)

Figure 3: Correlation between incidence of covered kernel smut in the short and long rains (KARI, Katumani, 1999-2000)

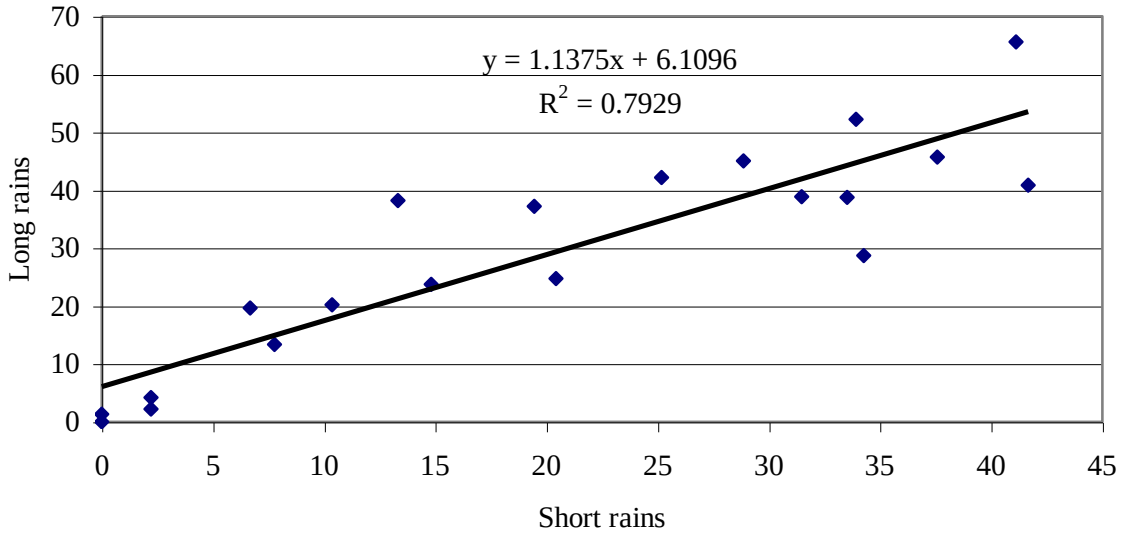
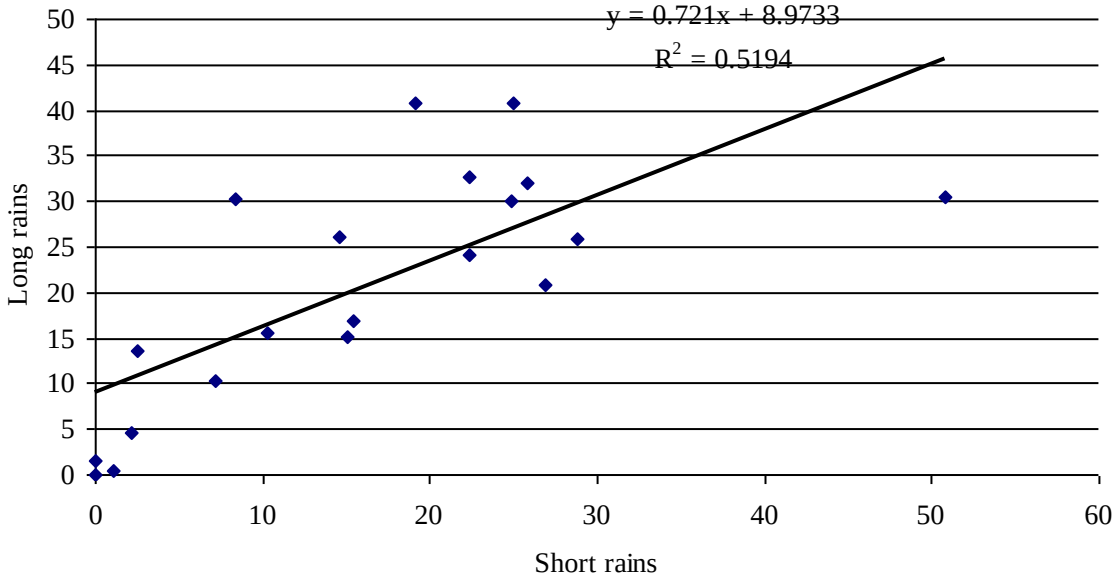


Figure 4: Correlation between the severity of covered kernel smut in the short and long rain seasons (KARI, Katumani, 1999-2000)



Incidence of stem borers

In the second season, commencing March 2000, the numbers of sorghum plants showing stem borer damage at the 5-7 leaf stage, was high in all the treatments (Table 26). There were no significant differences between incidence of stem borer on crops grown with the different pest control methods ($p = 0.473$). The accumulated analysis of deviance for treatments was 0.378, the short rain effect 0.473 and position in the field 0.476. The later figure indicates that there were no significant differences between the blocks. The lowest predicted incidence of stem borer was 54.6% in the direct-planted, blanket protection treatment (T9) and the highest was 90.9% in the treatment which did not include a CKS control element (T2) (Table 26). The observed incidences for T1, T2, T3, T4, T5, T6, T7, T8, T9 and T10 were 83.9, 89.0, 78.3, 86.4, 81.7, 88.4, 76.0, 76.3, 62.2 and 87.1% respectively. There was no significant difference ($p \leq 0.05$) between the predicted incidence of stem borers in direct planted and ratooned, with 76.1% and 86.6% respectively. The observed values were 76.4% in the direct planted crop and 85.4% in the ratooned crop.

The direct-planted crop failed to reach maturity, so only the ratooned plots were assessed. The level of stem borer damage at crop maturity was measured by the average length of tunnelling (Table 27), number of larvae (Table 28), and pupae per stem (Table 29). The average tunnelling length per stem was affected significantly by the treatments ($p = 0.007$) and little of the variation was due to a carry-over effect from the short rains ($p = 0.201$). The average predicted tunnelling length was longest (30.6 cm) in the ratooned plots treated with Karate only (T6), followed by treatments T2, T4, T8 and T10 with predicted average tunnelling lengths of 30.6, 29.2, 23.6, 19.9 and 4.8 cm (Table 27). The blanket protection treatment (T10) had significantly less ($p \leq 0.05$) predicted tunnelling than T2 and T8. The other treatments were not significantly different from each other. The actual values for T2, T4, T6, T8, and T10 were 30.2, 29.3, 28.6, 15.2 and 4.0 respectively. The relationship between stem borer tunnel length in short and long rains was not strongly correlated, with a trendline accounting for only 10.8% of the variation in the data. The slope of the line indicates that there is a positive correlation, with levels higher in the long rains compared to the short rains (Fig 6).

The predicted number of larvae per stem was low at between 0.1 and 0.7 larvae per stem. The majority of variance in the plots was accounted for by the carry-over effect from the short rains ($p = 0.017$). There were no significant differences ($p = 0.234$). The predicted number of larvae per stem was lowest in the blanket protection treatment (T10) with a predicted number of 0.1 and the highest in T2, T6 and T8, with a predicted number of 0.7 (Table 28). The actually observed values for T2, T4, T6, T8, and T10 were 0.8, 0.8, 0.6, 0.4 and 0.2. The predicted number of larvae per stem was low at between 0.5 and 0.0 and there were no significant differences between the treatments ($p=0.401$). The highest number of pupae were predicted in the treatment which did not include a CKS control element (T2) and the lowest in the blanket protection treatment (T10), with 0.5 and 0.0 respectively (Table 29). The relationship between incidence of stem borer larvae in short and long rains were not strongly correlated, with a trendline accounting for only 25.8% of the variation in the data. The slope of the line indicates that there is a positive correlation with levels higher in the long rains compared to the short rains (Fig 5).

Table 26: The effect of control treatments and ratooning on the incidence of stem borer (%) per treatment at crop stage 5-7 leaf (KARI, Katumania, March – July 2000)

Treatments	Observed incidence (%)	Transformed data		Back-transformed data	
		Prediction	s.e	Prediction (%)	95% cl
T1	83.9	1.670	0.527	84.2	(65.4, 93.7)
T2	89.0	2.297	0.670	90.9	(72.8, 97.4)
T3	78.3	1.359	0.546	79.6	(57.2, 91.9)
T4	86.4	1.518	0.577	82.0	(59.6, 93.4)
T5	81.7	1.736	0.559	85.0	(65.5, 94.4)
T6	88.4	2.158	0.655	89.6	(70.6, 96.9)
T7	76.0	1.182	0.532	76.5	(53.5, 90.3)
T8	76.3	1.218	0.482	77.2	(56.8, 89.7)
T9	62.2	0.184	0.520	54.6	(30.3, 76.9)
T10	87.1	2.165	0.573	89.7	(73.9, 96.4)
Total direct planted	76.4	1.156	0.205	76.1	(68.0, 82.6)
Total ratooned	85.4	1.869	0.245	86.6	(80.0, 91.3)

Table 27: The effect of control treatments on the mean stem borer tunnel length (cm) per stem (KARI, Katumani, March - July 2000)

Treatments	Observed length (cm)	Unbalanced data		
		Prediction	s.e	95% cl
T2	30.2	29.2	3.7	(21.7, 36.8)[2]
T4	29.3	23.6	6.0	(11.1, 36.0)
T6	28.6	30.6	4.1	(22.2, 39.1)[2]
T8	15.2	19.9	4.7	(10.3, 29.6)
T10	4.9	4.8	3.8	(0, 12.6)[1]

Key: [1] = significantly different ($P \leq 0.05$) from direct-planted, nil control treatment (T2)
[2] = significantly different ($P \leq 0.05$) from ratooned, blanket protection treatment (T10)

Table 28: The effect of control treatments on the mean number of stem borer larvae per stem per treatment (KARI, Katumani, March – July, 2000)

Treatments	Observed length (cm)	Unbalanced data		
		Prediction	s.e	95% cl
T2	0.8	0.7	0.2	(0.3, 1.1)
T4	0.8	0.6	0.2	(0.2, 1.1)
T6	0.6	0.7	0.20	(0.3, 1.1)
T8	0.4	0.7	0.2	(0.3, 1.1)
T10	0.2	0.1	0.2	(0.0, 0.5)

Table 29: The effect of control treatments on the mean number of stem borer pupae per stem per treatment (KARI, Katumani, March - July 2000)

Treatments	Observed length (cm)	Unbalanced data		
		Prediction	s.e	95% cl
T2	0.5	0.513	0.178	(0.1458, 0.8792)
T4	0.3	0.300	0.192	(-0.0961, 0.6964)
T6	0.3	0.283	0.182	(-0.0910, 0.6574)
T8	0.1	0.127	0.168	(-0.2188, 0.4723)
T10	0.0	0.002	0.183	(-0.3749, 0.3796)

Figure 5: Correlation between the incidence of stem borer larvae in the short and long rains (KARI, Katumani 1999-2000)

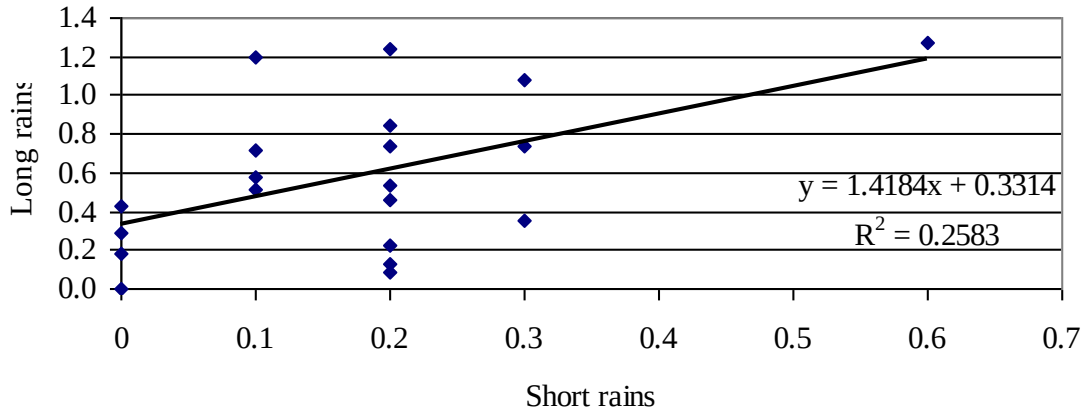
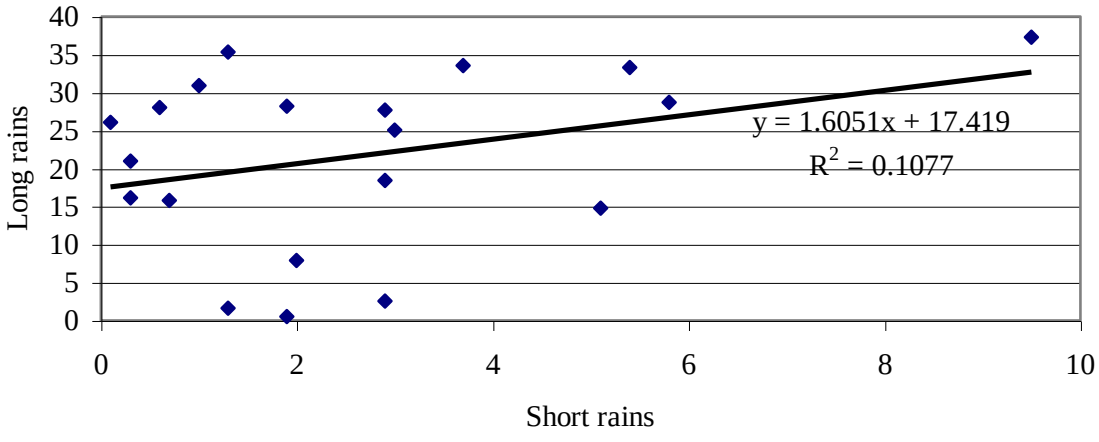


Figure 6: Correlation between stem borer tunel length in short and long rains (KARI, Katumani 1999-2000)



Activity 4.2: On-farm evaluation of ratooning in Mwingi district, Kenya

The activities described in the PMF are reported in this section. Additional data was collected which will support the publication of this work in a refereed journal at a later date. The complete report of the initial PRA undertaken is given in Appendix 5.

The focussed survey revealed that farmers were aware of the practice of ratooning sorghum after harvest of the short rains crop. This practice is confined to the traditional sorghum variety Muruge and, to a lesser extent, sorghum variety Muhuu. These varieties require sustained growth over both the short and long rains seasons in order to produce acceptable yields. These varieties are very tall (2.4 m) and tiller profusely. Furthermore, the tillering and associated pseudostem and root system is beneficial in reducing soil erosion in these areas. Many farmers recognise the value of this and these varieties are often sited on steep gradients.

There was variation in the methods used by farmers to ratoon. They had not considered the potential of ratooning the shorter duration, improved varieties which are now available to them (i.e. Seredo, Karimatama 1, Gadam el Hamam and PGRCE216740).

Farmers did not cite any specific disadvantages of ratooning improved varieties. Two farmers suggested disadvantages of ratooning in general were stem borer damage and a combination of stem borer and bird damage. One farmer considered the damage caused by stem borers and birds so great that he had abandoned the practice of ratooning sorghum.

Methods of ratooning varied between the two locations (Table 30). In Nguuku, ratooning of sorghum is undertaken soon after harvest (66 % of farmers interviewed). Of these farmers, only one reported reducing (thinning) the number of tillers by removing the oldest and leaving the youngest four to develop. The advantages of thinning are that the youngest tillers produce the more vigorous and healthier growth, and stem borer damage is reduced. Another farmer described a change in her practice from ratooning at the onset of the rains, to ratooning after harvest. The reason given was that this increased plant survival and reduced the damage caused by stem borers. The farmers who ratoon their sorghum at the onset of the rains also removed the tillers affected by stem borers. This tended to be the older tillers, leaving the youngest ones to develop.

In Kamuwongo, the most common ratooning practice cited was to ratoon soon after harvesting (53%). However, unlike in Nguuku, 33% of farmers in Itivanzou ratooned the sorghum as it reached physiological maturity. They then stooked (heaped) the stems with the heads still attached under a tree to dry. The reason given was that this reduced bird damage and if the plant is left to dry before ratooning, it does not tiller. Sorghum variety Muveta was not ratooned by any farmer. The reasons given were that it matured too early and therefore was badly attacked by birds. None of the farmers thinned the tillers after ratooning.

Table 30: Ratooning methods practised by the farmers in Nguuku and Kamuwongo locations, Kenya

Methods of ratooning	Number of farmers / location		
	Nguuku (12 farmers)	Kamuwongo (18 farmers)	Total
• At crop maturity, stems are cut and staked under a tree to dry, then heads harvested. No tillers removed	0	5	5
• Simultaneous harvesting and ratooning	1	1	2
• Ratoon soon after harvest, thinning to leave approx. 4 of the youngest tillers	1	0	1
• Ratoon soon after harvest, no thinning	5	7	12
• Ratoon immediately before onset of rains	2	1	3
• No ratooning practiced	1	3	4
• No answer	2	1	3

Based on the results of the on-farm experiments in both seasons, farmers were able to identify advantages and disadvantages of the four experimental treatments (Tables 31, 32, 33 & 34). This information provided both the extension services and participating farmers with clear examples on which to base future decisions or advice on ratooning. Overall, farmers considered that the practice of ratooning was beneficial to their farming system.

Table 31: The advantages and disadvantages of ratooning soon after harvest, no thinning (treatment 1) as listed by the farmers in Nguuku and Kamuwongo locations, Kenya.

	Location of farmers participating	
Nguuku: Group 1	Nguuku: Group 2	Kamuwongo
Advantages		
• flowers and matures early • produces a good yield with large heads • early harvest • not seriously affected by stem borers	• tillers early • produces many tillers • flowers and matures early • early harvest • early tillers are not as badly affected by stem borers	• tillers early • matures early • good yield
Disadvantages		
• none	• the numerous tillers compete with each other and the heads are smaller	• if the short rains are less than expected some stumps dry completely

Table 32: The advantages and disadvantages of ratooning soon after harvest, thinning to leave approx. 4 of the youngest tillers (treatment 2) as listed by the farmers in Nguuku and Kamuwongo locations, Kenya

	Location of farmers participating	
Nguuku: Group 1	Nguuku: Group 2	Kamuwongo
Advantages		
• none	• Flowers and matures early • produces large heads • tillers healthy because fewer in number • tiller produced early and grow quickly	• good yield • bigger heads than T1
Disadvantages		
• poor tillering • low yield • affected by stem borers • many stumps dried up	• do not like to uproot growing plants • thinning takes time and effort • if remaining tiller affected by smut or stem borers the yield is low	• none

Table 33: The advantages and disadvantages of ratooning immediately before onset of rains(treatment 3) as listed by the farmers in Nguuku and Kamuwongo locations, Kenya

	Location of farmers participating	
Nguuku: Group 1	Nguuku: Group 2	Kamuwongo
Advantages		
• none	• surviving stumps are easy to see • surviving stumps produce a good harvest	• none
Disadvantages		
• poor tillering • removed tillers had used water to grow	• tiller produced later resulting in later harvesting	• after ratooning, the rain entered the cut stem and caused rotting in some stems
• remaining tillers badly affected by stem borers • Many stumps dried • low yield	• many stumps dried before ratooning • many stumps died after ratooning	• plants were ratooned at a higher height and the resulting tillers on these stems broke off in the wind
	• late ratooning resulted in higher levels of pest damage	

Table 34: The advantages and disadvantages of direct sown sorghum (treatment 4) as listed by the farmers in Nguuku and Kamuwongo locations, Kenya

	Location of farmers participating	
Nguuku: Group 1	Nguuku: Group 2	Kamuwongo
Advantages		
• none	• good germination and vigour • good crop if the rains are good • need to till the soil	• none
Disadvantages		
• poor germination	• susceptible to pest attack, especially in low rainfall	• plants dried before reaching flowering stage due to low rainfall
• did not flower • high level of stem borer damage		• a lot of stem borer damage

Output 5: Broadening the cropping base to enhance food security in sorghum cropping systems in Tanzania

Activity 5.1: On-farm evaluation of seed sanitation practices for the control of sorghum covered kernel smut, Dodoma Rural, Tanzania

On-farm experiments were continued throughout the life of the present project allowing three consecutive seasons of on-farm data to be collected. A summary of the results for each location is given below and the analysis presented in Appendix 6.

The most effective way to eradicate covered kernel smut is to use a fungicide seed treatment. However, a consistent and improved level of control could be achieved through the practice of clean seed selection (*safi*). A summary of the data is presented below in Tables 35 – 38.

Table 35: Summary data from Mpalanga on control of covered kernel smut

Variety	Treatment	% plants infected with covered kernel smut		
		Season		
		1999 / 2000	2000 / 2001	2001 / 2002
Lugugu	Lundo	11.3	40.4	27.3
	Safi	4.0	14.8	14.3
	Dawa	0.3	0.3	0
Pato	Lundo	16.0	18.2	24.0
	Safi	1.7	14.0	6.3
	Dawa	0	0	0
Tegemeo	Lundo	19.3	36.7	23.0
	Safi	5.6	14.0	9.0
	Dawa	1.0	1.1	0

Table 36: Summary data from Mloa Barabarani on control of covered kernel smut

Variety	Treatment	% plants infected with covered kernel smut		
		Season		
		1999 / 2000	2000 / 2001	2001 / 2002
Lugugu	Lundo	25.5	71.3	27.3
	Safi	13.4	17.3	14.3
	Dawa	0	0	0
Pato	Lundo	24.3	19.0	24.0
	Safi	15.3	14.0	6.3
	Dawa	0	0	0
Tegemeo	Lundo	22.0	37.0	23.0
	Safi	5.3	14.0	9.0
	Dawa	0	1.2	0

Table 37: Summary data from Msanga on control of covered kernel smut

Variety	Treatment	% plants infected with covered kernel smut		
		Season		
		1999 / 2000	2000 / 2001	2001 / 2002
Lugugu	Lundo	26.6	56.0	20.0
	Safi	10.0	28.0	15.0
	Dawa	1.0	0	0
Pato	Lundo	25.0	21.0	24.0
	Safi	8.0	17.0	20.0
	Dawa	0	0.5	2.0
Tegemeo	Lundo	26.0	21.0	24.0
	Safi	10.0	12.5	20.0
	Dawa	0.5	0	2.0

Table 38: Summary data from Farmer Training Centre, Bihawana

Variety	Treatment	% plants infected with covered kernel smut		
		Season		
		1999 / 2000	2000 / 2001	2001 / 2002
Lugugu	Lundo	3.6	20.6	11.0
	Safi	0	15.3	3.3
	Dawa	0	0.6	0
Pato	Lundo	1.2	21.3	6.0
	Safi	0.5	19.0	0
	Dawa	0	0	0
Tegemeo	Lundo	2.0	9.0	0
	Safi	0	14.0	0
	Dawa	0	0	0
Macia	Lundo	8.9	4.0	3.7
	Safi	2.0	0	1.4
	Dawa	0	0	0

Activity 5.2: Broadening the cropping base to include cassava- variety identification and establishment

The requirement for suitable high quality cassava material, adapted to the agro-ecological conditions found in Dodoma Rural was addressed by staff of the National Cassava Programme based at SRI, Kibaha. Two improved cassava varieties namely Mumba and HBL 95/005 (Hombolo '95) were identified at the commencement of the project for further multiplication at the ARI, Hombolo site. These varieties were chosen for their characteristics of drought tolerance, high yield potential (20-39 t/ha), pest and disease tolerance and good acceptability to consumers. Both these varieties are sweet and early bulking (12 months).

Cassava nurseries were established in December 2000 at the Farmer Training Centre, Bihawana. One acre nurseries were established of the varieties, Hombolo'95, Mumba and farmers' local. All field operations including phytosanitation were undertaken by the experienced agricultural officers of the FTC, guided by staff of the SRI, Kibaha. In the second year the area under cassava production at FTC was doubled. Regular agronomic and phytosanitary inspections were made at the FTC and weak plants or those showing symptoms of disease e.g. cassava mosaic virus were rogued out. There will be 6 ha of planting material ready for distribution in December 2002.

A cassava agronomy video has been produced during the project.

Activity 5.3: Farmer adoption of cassava

Farmer groups visited the FTC during year one of the project to see at first-hand the establishment and care of cassava. The farmers were also shown the project video on the agronomy of cassava.

The key to adoption is utilisation. A rapid rural appraisal undertaken whilst developing the PMF for the project reported here (R7518) showed that most of the farmers in the farmer groups had very limited knowledge of the variety of ways in which this crop could be utilised. This was addressed through provision of a cassava utilisation workshop facilitated by Mrs Mtunda and staff of SRI, Kibaha. This was held at the FTC on 16 – 18 October 2001. A record of this workshop is given in Appendix 7. A video was made which is available through ARI and the Extension services to assist further dissemination activities.

Activity 5.4: Stakeholder workshops to identify suitable sites for community cassava nurseries

These were held concurrently with the stakeholder workshops held at the end of the first season for farmer groups participating in the on-farm evaluation of seed sanitation practices for the control of sorghum covered kernel smut (Activity 5.1). The farmer groups at both Mlowa Barabarani and Mpalanga decided that the cassava nursery should be on communal land managed by the group.

Activity 5.5: Establishment of community cassava nurseries

An area of 0.5 ha was provided by the village authority for cassava multiplication at Mlowa Barabarani village. The plots were planted with 0.25 ha of Hombolo '95 and 0.25 ha Mumba. Cuttings were planted on 4/5 January 2001at a standard propagation density giving 10, 000 plants per acre. Establishment was moderate in the first year. After the cassava utilisation workshop in

October 2001, farmers re-appraised the importance of the cassava nursery and obtained a new site on "better" land. The nursery was re-established using cuttings from the first site and additional material from SRI in Decmber 2001. The effort made to relocate the nursery is an indication of the value the farmers had attached to the cassava. This was partly a consequence of the new knowledge gained by these farmers on the manner in which cassava could be used. A similar sized nursery was also established by the farmer group at Mapalanga village.

Some of the farmers at both locations already have established some cassava on their *shambas.* Through the resource now established at the FTC and in the villages, all members of the groups will receive cuttings to establish their own cassava in December 2002. The groups plan to sell some cuttings to assist in procurement of cassava processing equipment.

An overview of the inclusion of cassava in the sorghum smut project is given in the paper presented by Mrs Mtuda of SRI, Kibaha at the Final Stakeholder Workshop. The farmer views on the activity are presented in their accounts presented at the Farmers' "*Kwaheri*" Workshop. These reports are included in Appendix 8.

CONTRIBUTION OF OUTPUTS TO DEVELOPMENTAL IMPACT

The project activities in Kenya, Tanzania and Uganda have delivered outputs to develop and promote environmentally acceptable, integrated strategies to enhance food security in sorghum-based cropping systems in semi-arid areas for the benefit of poor people.

Project activities focussed on working with stakeholders to reduce yield loss of sorghum through promoting seed sanitation practices for the control of covered kernel smut. The technologies validated for seed sanitation are farmer-selection of disease-free seed or application of a fungicide seed treatment prior to planting.

The practice of selection of disease-free seed requires the farmer to recognise the disease and understand its life cycle. This has been facilitated in Kenya, Tanzania and Uganda, through a series of on-farm participatory trials in which farmers have learned to identify sorghum smuts and select disease-free seed. In this manner, the yield and quality of small-holder sorghum is greatly increased. Through the project activities, training has been provided resulting in a core of extension personnel with new knowledge enhancing the advice they can offer to small-holder farmers on control of sorghum smut diseases.

In Tanzania, promotion and dissemination of project outputs has been undertaken throughout Dodoma Rural and into neighbouring areas. This has been supported by development and targeted distribution of a booklet on the identification, biology and control of sorghum smut diseases (Appendix 10). The information contained in the booklet is presented in Kiswahili and illustrated with good quality colour plates. These features increase the booklet's acceptability and hence its impact. A colour poster has been produced on the identification and control of sorghum smut diseases to increase awareness and support distribution of the booklet. Specific events have been used to raise awareness of the outputs of this project. These include two radio broadcasts and exhibitions at the main *Nane nane* Agricultural Fair and its satellites.

Selection of disease-free seed by farmers depends on both their knowledge and the presence of an enabling environment. The uni-modal rainfall pattern in Dodoma Rural, Central Tanzania means that there is a single growing season (November – June). There is considerable pressure on household food security during the long "off-season". During that period, the immediate need to

provide food for the family is the principal concern and as a result, selected, disease-free sorghum may be used for food. Seed purchased from market at the beginning of the next season is likely to have a high incidence of seed-borne inoculum of covered kernel smut.

The identified constraint to uptake of sorghum seed sanitation practices was poor household food security. Cassava was identified as an additional food crop which could be consumed during the off-season. Varieties of cassava suited to the agro-ecology of Dodoma Rural were identified and high quality cuttings obtained from the National Cassava Breeding Programme. Community managed cassava nurseries were established in participating villages to bulk up this material. There is now sufficient material for distribution of cuttings to all households of the participating farmer groups, continuation of the community nurseries and surplus for sale.

Cassava was not widely grown in Dodoma Rural prior to the project activities. The crop was unpopular due to limited knowledge of its utilisation - it was usually served in a boiled and unpalatable form. A cassava utilisation workshop was used to demonstrate the wide range of appetising uses of cassava, which has stimulated interest and acceptance of this crop amongst participating communities.

Through the project activities, a simple, safe and effective strategy i.e. selection of disease-free seed, has been developed to reduce losses of the subsistence staple, sorghum. As yields increase, farmers may have more of this crop for sale. To address this marketing issue, a leaflet has been produced in Kiswahili and distributed; the leaflet outlines methods for threshing and cleaning harvested sorghum in order to attract the best price for any surplus sold. This information will allow stakeholders to gain maximum benefit from adopting seed sanitation practices.

The farmer groups provide a focus in the communities for exchange of information and co-operative activities. Those in Dodoma Rural have opened a bank account and deposited money from the sale of some of this season's sorghum harvest. They intend to add to this funds obtained from selling cassava cuttings. Their aim is to purchase a diesel-powered cassava chipping machine. This will enable them to process cassava on an increased scale and sell the products. In this manner, small enterprise will enhance the sustainability of the project outputs.

In Kenya, there are two cropping seasons per year. The short rains, October to February and the long rains, March to July. The developed seed sanitation practices are effective in controlling covered kernel smut. However, crop establishment is often poor in the long rains. Farmers may have to buy additional seed to replant the March sown crops. This constraint to adoption of seed sanitation has been tackled by evaluating the practice of ratooning. Crops may be cut back after the short rains harvest and allowed to develop during the long rain season. The root systems of these crops are already well established. In many cases, ratooning enables the farmer to achieve a yield on occasions when this is, otherwise, not achievable. A study was undertaken to evaluate the effect of ratooning on carry-over of key pests and diseases and there were found to be no significantly deleterious effects of this practice.

The contribution made to developmental impact by the outputs of this project cuts across a range of areas – crop protection, crop diversification, crop utilisation, marketing and livelihoods. Furthermore, achievements made are beneficial to the broader environment. The varieties used for production of ratooned sorghum develop dense pseudo-stems that reduce "run-off" of surface soil. The re-establishment of cassava in Dodoma Rural will effectively enhance soil conservation as the roots will assist in binding the soil and the crop will provide a windbreak. Use of dead cassava stems and leaves for firewood will help alleviate some of the negative impacts of fuel collection.

Seed-borne inoculum of sorghum covered kernel smut may be controlled by the application of fungicide seed treatment. Such treatment may be routine in many developed countries, but the chemicals may be unavailable or unaffordable to small-holder farmers in developing countries. The project outputs provide an effective non-chemical, seed sanitation practice. However, there are occasions when growers will resort to using seed treatment fungicide e.g. after crop failure when sources of seed used to replenish an area may be contaminated with smut. Throughout the project, stakeholders have been shown how to minimise operator risk and environmental hazard when applying seed dressings. Activities in Uganda have focussed on using seed treatment to show the positive value of seed sanitation in reducing losses due to covered kernel smut. A novel study was undertaken in Uganda to examine the residual control which seed treatment could achieve. It demonstrated that where fungicide seed treatment is used for sorghum, the total fungicide usage could be reduced by 30-60 %. The developmental impact of the project is that farmers now have the knowledge to evaluate fungicide treatment and have been provided with a suitable alternative - disease-free, seed selection. They can now make informed decisions on their strategies for controlling covered kernel smut.

There are markets for sorghum in which even judicial use of fungicides is inappropriate. A Ugandan brewery company has commissioned SAARI to multiply seed of sorghum cv. Epuripur. Although this variety has been demonstrated to be very susceptible to covered kernel smut, the technique of selecting disease-free seed is being used effectively to retain smut-free seed stocks. The project activities included production of a smut identification and control booklet in the local Ateso language (Appendix 10). Participating farmers in Teso now understand the process of seed selection. As a consequence, these farmers have the opportunity to act as out-growers for cv. Epuripur. The developmental impact of the project in Teso has thus been beneficial to both food security and income generation.

The crop protection options delivered by this project offer appropriate solutions to increase food security and improve livelihoods. Strong linkages have been developed between project staff (researchers and extension providers) and the communities they serve. This has been achieved through active farmer groups (Kenya, Tanzania and Uganda) and developing new and innovative linkages with teaching professionals (Kenya and Tanzania).

The extension message of seed sanitation is appropriate for inclusion in school agricultural education activities. Through collaboration with the education sector in Kenya and Tanzania, effective promotion and dissemination of the project outputs has been achieved with primary school children acting as a conduit for information. The process of engagement with teachers has been documented at all stages in Tanzania and an impact assessment of schools-based promotion through drama undertaken in Kenya. This information provides a blue-print which could be applied in different areas to promote the present outputs or other suitably appropriate messages.

The project partners value the achievements of the present project and have cited the need to further promote and scale-up the activities. The Tanzanian partners have articulated clearly their priorities for scaling-up and further promotion of the project outputs; and they have documented these (Appendix 8). Demand for further work in Kenya and Tanzania comes from both the farmers and the National Programmes.

The dissemination outputs of the project include five videos, two disease control booklets, two leaflets and a disease identification poster in Kiswahili. The Ugandan partners have drafted a similar poster in Ateso. Both the Ugandan partners at SAARI and the Tanzanian partners at ARI propose to further promote the outputs at their World Food Day initiatives in October 2002.

There are a number of publications resulting from the project outputs that can be developed by NRI and the project partners. A paper entitled "Participatory approaches to the development and dissemination of control measures for covered kernel smut in Dodoma region, Tanzania" has been accepted[1] for inclusion in the IPM Conference for sub-Saharan Africa, 8-12 September, 2002. The experiences of working with schools has attracted considerable interest and publication of a paper on this is considered a high priority

Dissemination

1. Refereed publications

Hayden N J, Mbwaga A M, Wilson K S L W (2002) Participatory approaches to the development and dissemination of control measures for covered kernel smut of sorghum in Dodoma Region, Tanzania 12 pp accepted for African Journal of Crop Science

Ngugi H K , Julian A M, King S B and Peacocke B J Epidemiology of sorghum anthracnose (*Colletotrichum sublineolum*) and leaf blight (*Exserohilim turcicum*) in Kenya

Ngugi H K, King S B, Holt J and Julian A M (2001) Simultaneous temporal progress of sorghum anthracnose and leaf blight in crop mixtures with disparate patterns. *Phytopathology* **91 (8) 720 – 729**

Wilson K S L and Hayden N J (2000) Access to the next generation for sustainable control of covered kernel smut of sorghum Poster presented at the Third Global Conference on sorghum and pearl millet diseases, Guanajuato, Mexico 23-30 September, 2000

2. Reports

Reference Type (as per NRIL green citation guidelines)	Citation Details	*Plea prev "sub*
Mbwaga A M and Hayden N J (eds)	Project conclusion workshops in Tanzania for project R7518 "promotion of sustainable control of coverd kernel smut of sorghum through broadening the cropping base 51pp	In pr
Hayden N J	Visit to Tanzania to undertake end-of-season activities in support of R7518 "Promotion of sustainable control of covered kernel smut of sorghum through broadening the cropping base	In pr
Hayden N J	Visit to Tanzania in support of A0935/R7518 "Promotion of sustainbable control of covered kernel smut of sorghum through broadening the cropping base. File note VS 8905 2-19 March 2002 6 pp	In pr
Hayden N J, Mbwaga A M, Hella P, Wilson K S L, Mndolwa S	Incorporation of awareness and control of sorghum smut diseases in the school curriculum: Seminar to compare different teaching methodologies and contribution to pathways for wide-scale dissemination of information. Report of a Seminar at St Monica's Hostel, Dodoma Rural, Tanzania held 6-7 October 2001 (Published January 2002) 59 pp	In pr
Hayden N J	Visit to Serere Agricultural and Animal Production Research Institute in support of project R7518 / A0935 "promotion of sustainable control of covered kernel smut of sorghum through broadening the cropping base". Back-to-office report of Visit 8681 11-16 November 2001. Pp 4.	In pr
Hayden N J	Report of cassava utilisation workshop held at the Farmer Training Centre, Bihawana, Dodoma Rural, 9-11 October 2001 12pp	In pr
Hayden N J	Visit to Tanzania in support of project R7518 / A0935 "promotion of sustainable control of covered kernel smut of sorghum through broadening the cropping base" and project R7569 / A0940 2Participatory promotion of disease resistant and farmer acceptable Phaseolus beans in the Southern highlands of Tanzania. Back-to-office report of Visit 8661 4-16 October 2001.	In pr
Wilson K S L	Report of KARI / NRI sorghum pathology project on sorghum ratooning activities in Mwingi District – summary of on-farm trials (January – August 2001) and end-of-season workshops. Pp 12.	In pr
Mbwaga A M, Wilson K S L, Hayden N J, Hella J	Fahamu Magonjwa ya Fugwe (smut diseases) na Athari za Kiduha (Striga) Kwenye Mtama Katika Mkoa wa Dodoma. Reference guide to identification and control of sorghum smut diseases and Striga in Dodoma Rural. Pp 8.	In pr
Wilson K S L	Visit to Kenya in support of project R7518 / A0935 "promotion of sustainable control of covered kernel smut of sorghum through broadening the cropping base Back-to-office report of visit 8641. Pp 20	In pr
Hayden N J	Visit to Kenya and Uganda in support of project A0935 "promotion of sustainable control of coverd kernel smut of sorghum through broadening the croping base. Back-to-office report of Visit 8481 16-28 July 2001	In pr

3. Other Dissemination of Outputs

- End of season farmer workshops in Mlowa Barabarani and Mpalanga Villages in Dodoma Rural, Central Tanzania in June 2000 and May 2002
- Two farmer workshops in each of two cropping season over the life of the project i.e. 18 farmer workshops in Mwingi District, Kenya
- Presentation of a poster on identification and control of sorghum smut diseases at the *Nane nane* agricultural show in Tanzania. The poster supported distribution of the booklet produced during the project on identification and control of smut and striga on sorghum in Dodoma Tanzania
- Interschool-drama competition held in Kenya (March 2002) for promotion of the extension message of control of covered kernel smut
- Incorporation of the extension message for control of covered kernel smut of sorghum in Tanzania into the teaching activities of 15 primary schools. Each school undertook a range of dissemination activities
- Five project videos produced
    - Cassava utilisation
    - Cassava agronomy
    - Seminar on incorporating agricultural knowledge into the school curriculum
    - Plant pathology at Msanga primary school, Tanzania
    - Inter-schools drama competition, Kenya

      Note these last two outputs have also been transferred to CD

- Two project conclusion workshops in Tanzania
    - Stakeholder workshop to review project achievements and identify opportunities for scaling up. This was attended by the Deputy Director for Research, Dr G G Mitawa and representatives of Districts surrounding the project location _ Dodoma Rural
    - Farmers' *Kwaheri* workshop to obtain feed-back and impact assessment from participating farmers in Dodoma Rural, Tanzania
- Two radio broadcasts on Tanzanian national radio.