CROP PROTECTION PROGRAMME

Integrated management of *Striga* species on cereal crops in Tanzania

R7564 (ZA0369)

FINAL TECHNICAL REPORT

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March 1999 to March 2003

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Natural Resources Institute

FINAL TECHNICHNICAL REPORT

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EXECUTIVE SUMMARY

Project Purpose: This was: "Strategies developed to reduce impact of pests, and stabilise yields in semi-arid cereal-based cropping systems for benefit of poor people." The specific objective was to develop and evaluate approaches for the control of *Striga* species in maize, sorghum and upland rice based cropping systems in Tanzania. The project partnership, involving Ilonga Agricultural Research Institute and Sokoine University of Agriculture in Tanzania and the University of Sheffield and Natural Resources Institute, UK, undertook work in farming communities in three areas of Tanzania to develop and promote cost-effective *Striga* management practices. Addressing this challenge had the potential to contribute to a reduction in the impact of these parasites on cereal crops, leading to more stable levels of production for households whose major source of livelihood is agriculture. On-farm studies were undertaken on sorghum in Central and Lake Zone and on rice in Kyela district of Southern Highlands zone. Additional on-station trials were undertaken here and on maize in Eastern zone. Laboratory studies were conducted at University of Sheffield and Mlingano Agricultural Research Institute.

Output 1. *Striga* tolerant sorghum cultivars validated by farmers and promoted to uptake pathways: Farmer groups in four villages evaluated a set of sorghum lines in on-farm trials for four seasons. Results on reaction to *Striga*, yield performance and farmer perceptions of a range of crop traits, including maturity, drought tolerance, use and marketing, identified two lines which have the potential to raise sorghum productivity on *Striga* infested land. Supporting information on their performance was collected over three years of replicated trials at three infested and one *Striga* free site. Registration for release was obtained for these in November 2002 as the cultivars Hakika and Wahi. Breeders seed of each cultivar was produced at Ilonga and was under multiplication as foundation seed during the 2003 season. Information about the cultivars has been distributed to extension staff in semi-arid, sorghum growing districts. The project also facilitated discussion by extension and partner NGOs to explore opportunities to include the new cultivars in local seed multiplication initiatives in future.

Output 2. Predictive tool for assessing Striga tolerant sorghum cultivar x soil fertility interactions developed and evaluated: Discussions with and a survey of farmers identified the key soil types on which sorghum is grown and where *Striga* is a problem. Available nitrogen of these soils was determined to be very low by routine analytical techniques. Laboratory trials were undertaken, supplying nitrogen at a similar level to that found in the field. Cultivars Hakika and Macia showed greater tolerance to *Striga* than the widely grown cv. Pato, with infected Hakika performing consistently well at all nitrogen availability's. These results indicate that P9406 has the greatest tolerance of *Striga* at higher N availability's, with P9405 having the most consistent response to *Striga* infection where N supply is variable, in terms of losses in stem biomass on infection. These results were supported by field trials in which two levels of manure were applied. Manure was demonstrated to suppress *Striga* and increased grain yield. These findings were used to develop guidance on the deployment of new cultivars in Tanzania in the form of a decision support tool. This decision tree considers soil type and farmer access to manure or fertiliser. Hakika is recommended over other cultivars on extremely infertile and variable *luseni* and *itogolo* soils (Lake Zone) and *isanga*, *isanga chitope*, *ngogomba* and *nkuluhi* soils (Central Zone). *Wahi* is recommended on more consistent, fertile *mbuga* and *ibushi* soils (Lake Zone), although Hakika and Macia are also good choices for these soils.

Output 3. Integrated management options for production of *Striga* tolerant sorghum cultivars validated by farmers: Farmer groups evaluated use of manure and inter-cropping of sorghum with either cowpea or groundnut. Further evidence was obtained of the value of using manure to increase sorghum productivity on *Striga* infested land. Upwards of 50% of households do not use

manure but it is an option for those who have cattle, can afford labour for transport or have fields close to cattle kraals. Inter-cropping gave variable results. Although farmers appreciate being able to harvest two crops from the same field, sorghum yields were depressed by competition from the legumes in seasons of poor rainfall.

Output 4. Approaches which facilitate farmer and other stakeholder understanding of *Striga* and *Striga* management options developed and evaluated: A number of learning tools, aimed at increasing farmers' knowledge of *Striga* and possible management options were evaluated with farmer groups and discussed with extension mangers. Farmers favoured field plots, a simple rhizatron, or pots for demonstration of the host/parasite relationship, as these provide an opportunity to participate fully in learning. Posters and leaflets, the radio and drama could have supporting roles but were not thought to be as effective as more "hands on" approaches by which farmers "learn by doing".

Output 5 *Striga* tolerant maize cultivars based on known traits identified: Field and laboratory trials led to the identification of maize lines which have the potential to perform well on *S. asiatica* infested land. Two mechanisms were implicated, low production of *Striga* germination stimulant (xenognosin) and the failure of the parasite to develop after attachment. Crossbreeding of the low xenognosin-producing and *Striga*-tolerant lines could produce cultivars that perform exceptionally well on *Striga*-infested soils by combining the two mechanisms.

Output 6 Striga management options for upland rice developed and evaluated: Breeding lines of rice from WARDA in West Africa were tested in the field. One appears to support few emerged *Striga* but further work is needed to determine its yield potential under farmer management. The value of urea for suppression of *Striga* and boosting upland rice yields was confirmed in on-farm trials. Farmers however showed more interest in using the green manure *Crotalaria* to improve soil fertility. This was evaluated on research-managed plots and planted by farmer groups. Wider promotion of rice/legume rotations on *Striga* infested land is now being supported by CPP in two areas of Tanzania.

Additional outputs: A review of *Striga* research needs was undertaken in Uganda. Recommended outputs and activities have been incorporated into a project undertaken by Serere Agricultural and Animal Research Institute and funded by the DFID supported CORF programme. The project facilitated discussions at two stakeholder workshops held in March 2003, to validate the findings of a review of crop protection promotion opportunities in semi-arid areas of East Africa.

Contribution of Outputs to Project Goal: The technologies developed and assessed by this project have the potential for adoption over large areas of Tanzania where *Striga* is a problem, provided they are adequately packaged and promoted in future NGO or district extension programmes. These technologies largely lack the need for repeated, seasonal external inputs but they are knowledge intensive. Studies have been undertaken by the project in partnership with government institutions, SUA and NGOs that have progressively adopted a client-oriented approach. Work has been completed in rural communities on-farm within the associated constraints of unreliable weather and unpredictable pest and disease attack. The varieties and practices identified for future promotion are robust and offer resource poor farmers the opportunity to increase yield and farm productivity. This project has encouraged collaboration of institutions at district and zonal level. This experience and the low-input technologies validated by farmers will be valuable to a number of institutions in Central and Lake Zones as they continue to evolve and plan to scale up promotion of practices which have a real chance of helping the poor.

BACKGROUND

Importance of the researchable constraint

The semi-arid areas of East and Southern Africa cover approximately one-third of the land area and support one quarter of the population of the region. Because of inherent resource limitations and a risk prone climate for arable agriculture, these areas include some of the poorest sectors of the population. Many rural households in this environment are regularly under food-deficit and poverty limits their capacity for investment in crop production, or resource conservation. *Striga* species are noxious weeds that are widespread constraints to the production of staple cereal crops in semi-arid areas, principally attacking finger millet, maize, sorghum, and upland rice. They have been estimated to infest some 40% of the cereal producing areas of sub-Saharan Africa; *S. hermonthica* alone may now infest over 10 million hectares (Sauerborn, 1991).

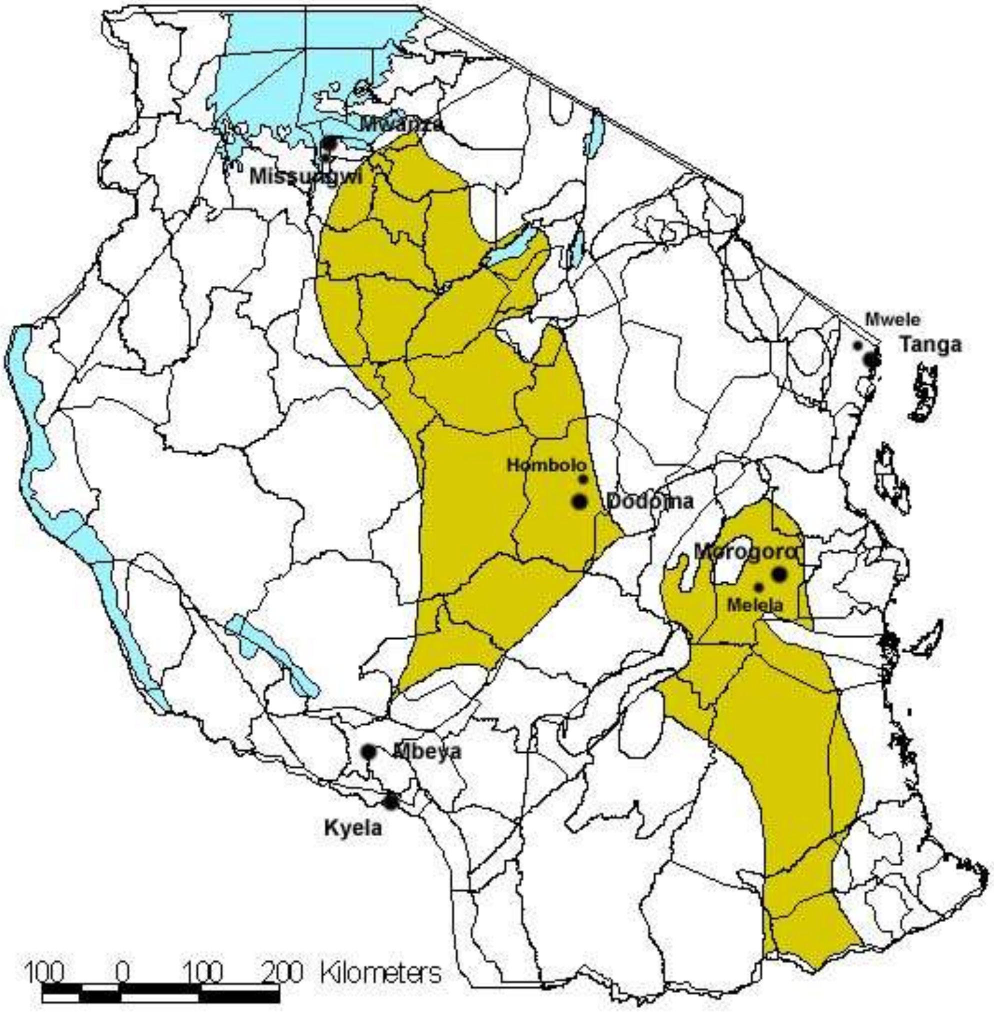
Semi-arid areas of Tanzania (Figure 1) lie in a zone where the three most significant *Striga* species which infest cereals i.e. *S. asiatica, S. forbesii* and *S. hermonthica* occur. Most of the districts in semi-arid areas of Tanzania have been surveyed (Figure 2) and the distribution of *Striga,* found throughout these areas, is broadly known (Mbwaga 1994; Mbwaga 1996). Grain yield loss from parasitised cereal crops is difficult to estimate with any reliability due to variations in soil fertility, infestation levels and tolerance of local varieties. Reports of 5-30% loss of potential yield, with crop failure at heavily infested sites are common in the literature for various parts of Africa. Other consequences of *Striga* infestation include farm abandonment, now difficult in the face of a shortage of productive arable land, or a change of cropping pattern to less favoured, albeit resistant crop species. Reichmann *et al.* (1995) reported that 75% of farmers interviewed in Shinyanga region of Tanzania considered *Striga* an increasing problem on sorghum, on which they were unable to obtain satisfactory advice from extension on effective control strategies. Work by CPP project R6654 has shown how sorghum, the preferred staple, has been replaced by pearl millet which is not attacked by *Striga* in parts of Missungwi district in Mwanza Region. In Kyela district of Mbeya Region cassava has increased in importance as a less profitable break crop, where once farmers had a rice mono-culture, due to declining soil fertility and a build up of *Striga* (Mbwaga *et al*., 1998). CPP Project R6921 has shown that maize, the preferred staple in the Eastern Zone, is severely attacked by *S. asiatica*, yet there are few, if any, recommended control strategies. Farmers generally have little knowledge of the biology of *Striga* or are aware of effective management strategies (e.g. Shaxson *et al*., 1993). Studies undertaken by R6654 in Dodoma Rural district showed however that farmers are well aware that poor sorghum yields are the norm in infested fields and that poor crop vigour and *Striga* are associated with declining soil fertility (Mbwaga *et al*., 1998).

Despite the low productivity of sorghum based systems less than 2% of the area in semi-arid Tanzania is currently planted to improved cultivars (ICRISAT/SMIP, 1998). Field work undertaken by R6654 confirmed that those which are available, Tegemeo and Pato, are susceptible to *Striga*. Shorter duration cultivars, that are less susceptible to *Striga*, would provide farmers with the opportunity to gain an earlier harvest, reduce losses to *Striga* and reduce risk of production.

Demand for the project

Agricultural research and extension services in Tanzania have been re-structured to move the emphasis from a national programme to one of "client orientated research" based on Zonal priorities. These are developed via the Zonal Internal Programme Review (IPR) procedures. This

Figure 1. Semi-arid zones in Tanzania.



mechanism leads to the identification of priorities. CPP funded research to develop *Striga* management practices in Tanzania from 1996 to 1999 (R6654). A workshop for key stakeholders was held in Dar es Salaam at the completion of the project and this included a discussion of demand for a continuation of CPP support review of future *Striga* research priorities (Riches, 1999). Research and extension staff from the Lake, Central, Eastern, Southern and Southern Highlands Zones confirmed the importance of *Striga* in their areas. Participants developed the following ranking of the problem, based on previous IPRs and personal experience:

	Sorghum		**Maize**		**Upland Rice**	
Zone	**Crop**	***Striga***	**Crop**	***Striga***	**Crop**	***Striga***
Lake	H	H	M	H	NA	
Central	H	H	M	H	NA	
Eastern	L	M	H	M	L	L
S. Highlands	L	H	H	M	L[1]	H
Southern	H	M	M	L	L	L
Western	M	H	H	M	NA	
Northern	L	Unknown	H	L	NA	

[1] rice is however the priority crop in Kyela District

Importance – H = high; M = medium; L = low. NA = crop not grown or *Striga* is not an issue.

Sorghum is principally grown in Mwanza, Shinyanga, Tabora, Singida, Dodoma, Morogoro and Lindi regions. On the basis of the ranking the meeting decided that a new project should concentrate work on sorghum in Lake (Mwanza region) and Central (Dodoma) Zones. It was also agreed to screen maize cultivars suitable for Eastern zone, where lowland maize is infested by *s. asiatica* and to continue work on rice based systems in Southern Highlands zone. Rice is the dominant cereal crop in Kyela district of the Southern Highlands Zone. The district extension staff played a key role to set up the on-farm programme undertaken by R6654 in their area. An indication of the priority afforded to the *Striga* problem on rice locally is that the district council voted funds, for three financial years starting in 1999/2000, to allow the District Agricultural Officer and his staff to participate in a continuing research programme.

During project preparation CPP management requested the team to investigate extending support to Striga research in Uganda. The importance of Striga in semi-arid areas of Uganda had previously been established by a study undertaken for CPP (Riches, 1998). Agricultural research priorities for Uganda were set by the National Agricultural Research Organisation (NARO) in 1994. The published NARO research priority rankings, quoted by Brown and Poulter, (1997) indicate that, at the time, Striga was the highest ranked research priority for both finger millet and for sorghum. As part of the process of developing a client-led farmer participatory research agenda SAARI staff subsequently participated in needs assessments by Rapid Rural Appraisals in both Teso and Lango farming systems (Akwang et al., 1998; 1999). Sorghum and finger millet were confirmed as crops of major importance and in both systems the needs assessment revealed the importance of Striga and, the need for future work on its' control in these crops. For Teso, Striga was identified as a "Priority Agricultural system-wide issue". The report suggested that this should be addressed through the development of an IPM strategy and regional collaboration in Eastern Africa. For Lango areas the report similarly listed Striga in cereals as a "High Priority Agro-ecology-based crop and post-harvest issue". For sorghum, the development of resistant varieties and IPM packages were suggested as research activities.

Previous research

Striga in Tanzania: The broad distribution and devastating impacts of *Striga* across Africa have been recorded by numerous authors (e.g. Parker and Riches, 1993; Sauerborn, 1991). In Tanzania, severe infestations occur in finger millet, maize, sorghum and upland rice and their

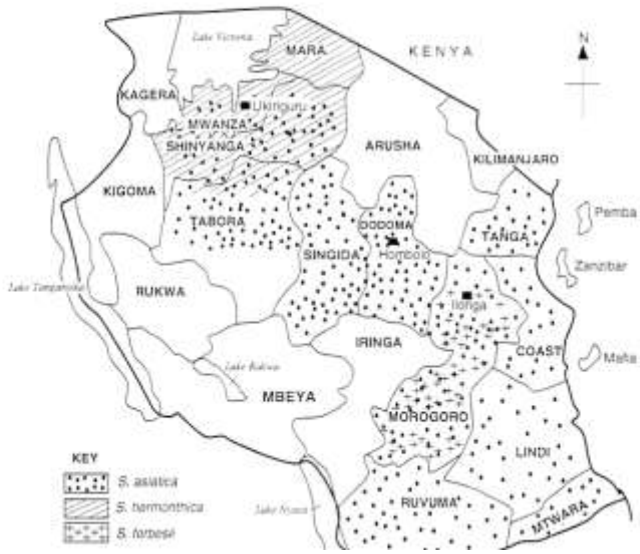


Figure 2. Distribution of *Striga* in Tanzania (Mbwaga & Obilana, 1993).

impacts are analogous to those found in other African nations (Mbwaga & Obilana, 1993). More recent survey work has been undertaken to fill gaps in the distribution of *Striga* shown in Figure 2. Notably, this and field studies undertaken by Project R6554, has shown the widespread occurrence of *S. asiatica*, and more local importance, of *S, forbesii* on maize and upland rice in Kyela district, Mbeya region at the north of Lake Nyasa.

The project was designed to build upon the outputs of R6654 and R6921 and activities were based upon a number of key concepts which need to be incorporated into *Striga* management programmes.

Selection and Validation of sources of resistance or tolerance to sorghum: Previous work in Tanzania and elsewhere in Africa, has identified promising levels of resistance (low numbers of emerged parasite) to *Striga* in sorghum (e.g. Parker and Riches, 1993; Mbwaga, 1996). On-farm and on-station trials were undertaken by R6655 in Lake Zone (*S. hermonthica* infested) and in Dodoma Rural District (*S. asiatica* infested). Low-susceptibility to both *Striga* species was confirmed for lines including P9405 ex-Purdue University, SAR29 and SRN39. This partial resistance is less pronounced at low fertility sites. During field days farmers selected these lines for further testing on the basis of low susceptibility, plant and grain type. Multiplication was undertaken at Ilonga to provide collaborating farmers with 0.5 kg per line in 1998/99. Farmers once again selected P9505, SAR29 and SRN39. In a season when the onset of the rain and planting was delayed from late December to late February these early maturing lines not only proved to be productive on *Striga* infested fields, but also provided mature grain at a time when the local landraces were still flowering. Supporting work in the glasshouse at LARS, in UK, confirmed that these lines are less susceptible to the parasite than the currently released cultivar Pato. Work in Sheffield (R6921) clearly demonstrated the differential sensitivity of sorghum genotypes to infection by *S. hermonthica* and *S. asiatica* (e.g. Gurney *et al*., 1999a; Gurney *et al*., 1999b). These differential responses result from: (i) partial resistance to *Striga* infection, expressed at the level of germination or attachment of *Striga* and/or (ii) tolerance of the host to infection where, host performance is little affected even when supporting high parasite biomass. Laboratory work in Sheffield has identified resistance traits in sorghum, including ex-Purdue University lines, P9405 and P9406, supporting field observations by project R6654. These sorghum lines appear to be low stimulant producers, preventing the germination and attachment of both *S. hermonthica* and *S. asiatica.* However, work at Sheffield University has unequivocally shown that low levels of *Striga* infection, even a few parasites, can have a significant effect on host productivity. The metabolic perturbations caused by the parasite outweigh the direct loss of resources to the parasite. This can be seen very clearly in studies of the impact of *Striga* density on host response, where a very large reduction in density is required before any significant impact on the host is observed (Gurney *et al*., 1999a). In the light of these findings a more desirable trait in terms of improved grain yield may be tolerance of a cultivar to infection.

On-station work was also undertaken to select for resistance among progenies provided by SADCC/ICRISAT and the sorghum breeder at Ilonga. Ten lines from more than 100 were retained for further testing following two seasons of selection at both Hombolo and Ukiriguru.

Tolerance and soil fertility: *Striga* development is generally hindered at higher nitrogen availability. Indeed, *Striga* is more of a problem where soil fertility is low (e.g. Agabwi and Younis, 1965), and higher nitrogen availability has been shown to suppress parasite germination and attachment (Smaling *et al*., 1991; Cechin and Press, 1993). However, project R6921 has shown that the success of nitrogen fertilisers in both reducing the density of emerged *Striga* plants and in improving grain yield has been equivocal. The response varies greatly both geographically (e.g. between countries) and spatially (between cropping seasons) and also as a function of crop species (sorghum and maize) and genotype. Thus, there is not a universal relationship between the minimum amount of nitrogen, its form and time of application, which is required to elicit economic benefits to subsistence and small holder farmers. For this reason, it is essential to understand how nitrogen perturbs the interaction between *Striga* and its cereal hosts, so that it can be used more efficiently with regard to interactions between genotype and environment. In particular it is important to determine any variability there may be in the response of tolerant sorghum genotypes to *Striga* on different soil types which differ in nitrogen availability so that farmers can be advised on the most appropriate line to grow.

Identification of tolerance traits in maize: Although maize is highly sensitive to infection by *Striga*, R6921 has shown that the fundamental responses of different cereals are very similar. This allows transfer of knowledge from sorghum to maize, enabling the search for traits that confer resistant in maize, based upon our understanding of those factors that alleviate the development of *Striga* on sorghum and its subsequent impacts on yield. Studies funded by R6921 in Kenya and Tanzania have identified maize cultivars that show great promise, with substantially smaller yield losses in the presence of *S. hermonthica*.

Development of integrated approach to Striga management: Trials conducted by R6654 concentrated on improving soil fertility through the use of animal manure or fertiliser, use of legume inter-crops, as components of Striga management. There has been considerable interest in these practices in research projects elsewhere. For work on fertility see Hess and Ejeta, 1987; Shaxson and Riches, 1998; on hand-pulling Carson, 1988; Ramaiah, 1995; inter-cropping/trap-cropping Robinson and Dowler, 1966; Parker and Riches, 1993; Webb, 1993; integration of methods Hess *et al*., 1996; Berner *et al*., 1996.

The challenge is therefore to incorporate appropriate management practices, which farmers can afford, within the crop management system for use with the most resistant cultivars that are available. It is important to target both a reduction in the parasite population and enhanced host productivity through increased soil fertility. Effective on-farm evaluation of *Striga* management practices must involve the farming community and R6654 has been working with farmer groups. In 1997/98 trials on farms in Iteja (Lake Zone) became water-logged and failed but sorghum work was completed successfully in Mwagala (Lake Zone), Mvumi Makulu, Hombolo and Chipanga (Dodoma). Reduced *Striga* attack was associated with application of cattle manure or inter-cropping with cowpea or groundnut. *Striga* resistance of P9405 and SAR 29 was more pronounced when these lines were grown in combination with an inter-crop or following application of manure.

Reduced *Striga* emergence has been shown to be associated with enhanced yields following application of urea, at affordable rates, to rice. Mean *S. asiatica* counts following application of 0, 25 or 50 kg ha^{-1} urea were 10.6, 6.7 and 3.0 plants m^{-1} while associated yields were 1756, 2474 and 3051 kg ha^{-1} respectively. Rice is an important cash crop in Kyela so fertiliser is a feasible technology for targeted use on *Striga* infested sites. *Crotalaria* for soil fertility improvement was also been introduced in trials at 27 sites in Kyela as part of 1998/99 programme. There were trials with the green manure on a few farms in the area some years ago and farmers are keen to have access to more seed. The effect on subsequent rice yield was to be evaluated in 1999/2000.

Assessment of farmer acceptability of Striga management options

Farmer perceptions, knowledge and practices: Baseline information about millet and sorghum-based systems in Dodoma region is available for the early 1990s (Holtland, 1994). In July 1997 RRA activities were undertaken by R6654 in three villages in Dodoma Rural District (Mbwaga *et al*, 1998). These led to an improved understanding of the *Striga* problem in the context of the farming system; generation of research priorities, initiation of farmer interest and planning of an on-farm trials programme. Discussions focusing on farmers perceptions of the *Striga* problem revealed that they have little knowledge of the biology of the pest, but that it is known to be associated with poorer soils and low sorghum yields. Control measures known by some farmers included: manure application, weeding or abandoning infested fields. In the case of manure application it is not known whether this is knowledge based upon experience or an extension message.

Villages in Missungwi District, Lake Zone, have provided a focus for many years of farming systems research undertaken by the Lake Zone Agricultural Research and Development Institute (LAZARDI), so the characteristics of the farming system and changes in cropping practices are well known (e.g. Kileo, 1996, Meertens *et al.*, 1995). There has also been a long history of research on soils and farmers' perceptions of soils in the area (Oudwater *et al*., 2000). Declining soil fertility is perceived by farmers as a problem, particularly with upland soils, as is *Striga* on *mbuga, ibushi* and *itogolo* soils.

A study of the farming systems in Kyela district was undertaken in the early 1990s and this provides useful baseline information on conditions in the area (ICRA, 1994). The report emphasises the dominant role of rice as both a cash and food crop and the widespread perception of declining soil fertility on upland areas.

Farmer-extension-researcher interactions in assessment and promotion of Striga management options: Experiences with farmer groups formed to evaluate sorghum cultivars and *Striga* management technologies during R6654 showed the importance of providing farmers with adequate information on the life cycle of the parasite. Concepts underlying the use of resistant or tolerant cultivars and the range of cultural practices that are available are knowledge intensive. Training is therefore needed so that farmers can understand enough about *Striga* to adequately evaluate control measures or decide on adoption. A range of written training materials have been prepared in Tanzania over the past few years including posters showing key aspects of *Striga* life cycle and control options. A manual for training of extension workers and three pamphlets are also available. These include "Fahamu magonjwa ya fugwe na athari za kiduha kwenye mtama katika mkoa wa Dodoma" (Control of smut and *Striga* on sorghum) and "Jihadhari na gugu hatari" (That dangerous weed witchweed). Other approaches to increasing farmer awareness of *Striga* control have been used elsewhere in Africa including the development of pictures used to stimulate discussion in an extension setting (Kachelriess, *et al.,* 1996).

PROJECT PURPOSE

The Project Purpose was: "Strategies developed to reduce impact of pests, and stabilise yields in semi-arid cereal-based cropping systems for benefit of poor people." The specific objective was to develop and evaluate approaches for the control of *Striga* species in maize, sorghum and upland rice based cropping systems in Tanzania through the integration of techniques appropriate to smallholder farmers. A reduction in the impact of these parasites on cereal crops will contribute to more stable levels of production for households whose major source of livelihood is agriculture. Studies were designed to address the following issues:

- the farmer assessment of tolerant sorghum cultivars and cultural practices which reduce the impact of the parasite
- understanding the differential performance of sorghum cultivars under a range of levels of soil fertility
- the identification of traits which confer tolerance to *Striga* in maize
- farmer assessment of cultural practices which reduce the impact of *Striga* in upland rice
- the development of learning tools which can provide farmers with a greater understanding of the *Striga* problem

RESEARCH ACTIVITIES

Research partnerships

The project brought together agronomists, weed scientists and agricultural economists/socio-economists of the Department of Research and Development and Sokoine University of Agriculture in Tanzania, University of Sheffield and the Natural Resources Institute, UK with district extension staff in Tanzania. During the course of the project the following staff made inputs to this research:

Department of Research and Development, Tanzania

Ilonga Agricultural Research Institute, Kilosa

Dr A M Mbwaga, Co-ordinator of field activities in Tanzania
Dr S Mndolwa, Sorghum Breeder
Mr C Masawe, Agronomist

Mlingano Agricultural Research Institute, Tanga

Dr G Ley, Soil Fertility Specialist

Mpwapwa Agricultural Research Institute, Dodoma

Mr Mwanga, Agricultural Economist

Lake Zone Agricultural Research Institute, Ukiriguru

Mr Kapinga, Agronomist

Sokoine University of Agriculture, Morogoro

Dr J P Hella, Agricultural Economist
Mr Nyenkweli, Post Graduate student
Mr J Kayeka, Post Graduate student

University of Sheffield

Prof M C Press, Plant Physiologist
Dr J Scholes, Plant Physiologist
Dr S Pierce, Post-Doc Research Fellow
Dr J Watling, Post-Doc Research Fellow

Natural Resources Institute

Dr C R Riches, Weed Scientist and project leader
Mr R Lamboll, Agricultural Economist

District Extension staff

Staff from Missungwi District (Lake Zone), Dodoma Rural District (Central Zone) and Kyela District (Southern Highlands Zone),

Research sites

Work was undertaken in a number of areas of Tanzania in farming systems based on the production of three *Striga* susceptible crops. Farmer research groups had been established in all the villages where trials were conducted under the previous CPP *Striga* management project (R6654) or had participated in an earlier project on sorghum smut management (R6581). Key sites are shown on Figure 1.

Sorghum: On-farm trials were conducted with communities in Central and Lake Agricultural Zones. In Central Zone work was conducted on fields infested by *S. asiatica*, in the villages of Chipanga A, Mvumi Makulu and Mpalanga within Dodoma Rural District (Dodoma Region). On-station trial work was implemented at the Hombolo Agricultural Research Centre. The majority of inhabitants of the area are Wagogo, cultivating pastoralists who economically rely on crop production, particularly in Mvumi. Holtland (1994) summarised various sources of information available at the time on livelihoods and pointed out that the majority of households rely heavily on "off-farm" income including beer brewing, daily labour, charcoal burning, business, bee keeping and gifts/remittances. Crops accounted for about 16% of total income (including food eaten) while livestock represented a further 12%. The area has a short rainy season from December to April with an average rainfall of 566 mm. Pearl millet is the principal cereal crop accounting for 60% of the cropped area. Sorghum and maize each occupy 12% with legumes (groundnuts, bambara and cowpeas) usually grown as sole crops, also on 12% of the land. Apart from small-scale production of vegetables and sugar cane, the area lacks a widely grown cash crop that can be used to regularly generate significant cash income. Government policy has been to introduce cassava as a food security crop with production promoted by the use of by-law. Crops in Mvumi are produced under a minimum tillage system of hoe cultivation. This is also important in Chipanga but here there is greater access to animal draught for ploughing. Shortage of manure and the unavailability of transport are of concern to farmers. A recent survey in Mvumi showed that only 6% of households use manure and 3% inorganic fertiliser (Mhina, 1997). Holtland (1994) concluded "the soils are poor or very poor" and that N is the most limiting factor to crop production. On many fields, ash following the burning of crop residues, is the only mechanism for returning nutrients to the soil.

In the Lake Zone the on-farm trial programme was undertaken in Iteja and Mwagalla villages of Missungwi District (Mwanza Region) with on-station trials at the Lake Zone Agricultural Research and Development Institute, Ukiriguru. These sites are on soils that are infested by both *S. hermonthica* and *S. asiatica*.. The Wasukuma who inhabit the area are primarily agriculturists although they own significant numbers of cattle, used for ploughing (Meertens *et al*., 1995). The general pattern of rainfall is bimodal; most rain falls from November to December and from March to April. The variability in annual rainfall is considerable ranging from 530 mm to 1,479 mm at Ukiriguru in the period 1940 to 1990. On average there are two drought years every decade and famine occurred in 1929, 1944, 1949, 1970 to 1972 and 1982 to 1984. Food supplies were also short in 1991-92. Various survey data are quoted by Meertens (1995) to give a general picture of crop production in the early 1990s. Average cultivated area in Missungwi was 7.7 ha per household of which sorghum accounted for 0.9 ha. Maize, pearl millet and rice in years of good rainfall are also important cereal crops. Many families grew cotton at the time but few fields have been seen in the villages in which the CPP *Striga* projects have operated. Disused buying sheds indicate that cotton was once an important component of livelihoods in the area. Crops are grown on a number of different soil types with sorghum on upland sandy-loam *luseni* and heavier *mbuga* soils in valley bottoms. *Striga* infests both soil types. Cassava and sweet potato are important on upland fields with tomatoes and other vegetables increasing in importance. Chickpea is also produced as a cash crop in relay with sorghum on *mbuga* fields. As cotton has declined there has been an expansion in rice on hardpan *itogolo* soils, with surpluses sold in good years. In the early 1990s 50% of farmers were recorded as using some manure, particularly for maize production on sandy soils although 90% indicated they would like to use more. As in Central zone transport from kraals to distant fields is a major problem.

Additional research-managed cultivar trials were undertaken on a farmer's field rented for the purpose at Melela in Morogoro Rural District (Morogoro Region). Both S. forbesii and S. asiatica infest this site. *Striga*-free land at Ilonga Agricultural Research Institute, Kilosa (Morogoro Region) was used for seed multiplication.

Maize: Field work on this crop was restricted to researcher-managed cultivar screening trials. These were undertaken at a site infested by *S. asiatica* at Mwele Seed Farm located in Muheza District (Tanga Region in Eastern Agricultural Zone) and also at Melela.

Rice: All studies on upland rice were undertaken on-farm in the villages of Itope and Kilasilo located in Kyela District (Mebeya Region in the Southern highlands Agricultural Zone). Kyela district had an estimated population of 159,000 in 1994. High quality, aromatic rice, planted on about 44% of the districts agricultural land, is the most important food and cash crop in this largely rural district. Rice sales therefore represent one important source of income to farmers who store the grain from harvest in June/July until prices rise when traders visit in November. Rice is grown on upland and lowland fields, the latter becoming inundated after crop establishment. The majority of farmers prepare land with ox drawn ploughs. The Kyela District Office reported that by mid 1999, *Striga* was a serious problem on nearly 3,000 ha of upland rice in at least 5 village areas, with some 15% of the rice area in the district being severely affected. Although yield on infested fields can be increased by use of inorganic fertiliser, there is only limited access to credit for cash inputs. The scheme set up for farmers in Kyela requires them to repay the loan at harvest time when the rice price may be only 50% of the level when trading begins in November. Discussions with farmer groups participating with project R6654 indicated that few had made use of the credit system so fertiliser use for rice remained rare. Maize, cassava and some legumes, particularly bambara and pigeon pea inter-cropped with rice, are also produced. Tree crops are an important source of income for many households, particular cocoa that attracts a premium as “organic”, oil palm, citrus and cashew.

Research undertaken

Building upon the work of project R6654 the project continued to take a farmer centered approach with the majority of activities implemented through farmer research groups. Studies were planned to address the six outputs listed on the project log frame but subsequently additional work on two further outputs was added at the request of the CPP managers.

<u>Output 1. Striga tolerant sorghum cultivars validated by farmers and promoted to uptake pathways</u>: Two candidate *Striga* resistant sorghum lines (P9494 and P9406) identified by work undertaken by R6654, tolerant lines Weijita and SRN39 and two previously released cultivars, Macia and Pato were assessed by farmers in on-farm trials. Participants were given 0.5 kg seed of each line and planted the entries on adjacent unreplicated plots. Data on *Striga* emergence at 12 weeks after emergence and crop yield were recorded from an area of 5 x 5 m on each plot by village extension officers. Between 10 and 25 farmers planted the trial in each of Mwagalla, Iteja (Missungwi District), Mvumi, Chipanga (Dodoma Rural) and 5 established plots in Mpalanga (Dodoma Rural). Trials were undertaken in 2000, 2001 and 2002 planting seasons. In addition to technical evaluation mid-season field walks and group discussions were organsised with each village research group to explore farmer perceptions of the lines. A follow-up study was completed in early 2003 in Chipanga and Mvumi to determine the extent of farmer to farmer diffusion of seed and early adoption. A multiple visit survey of 58 project participants was undertaken with information collected on types of sorghum and amounts planted, yields, use in food, sales and donations to neighbours.

The six lines listed above were also planted in replicated “uniformity” trials at Ukiriguru, Hombolo, Mvumi, Melela and Ilonga (*Striga* free reference site) to generate statistically valid data for eventual use in an application to register P9405 and P9406 as cultivars for release in Tanzania. These trials ran for three seasons and were undertaken and managed according to the specification laid down by the Tanzania Official Seed Certification Agency (TOSCA). Data on a range of plant traits were collected as requested by TOSCA whose officials visited the trial sites and inspected plants for “trueness to type”. An application for registration was prepared and submitted to the National Seed Release Committee in November 2002.

Information on the traits of P9405 and P9406 (subsequently released as Hakika and Wahi) was presented to extension officers for sorghum growing districts of Central and Lake Zones at the end of project workshops in March 2003. A fact sheet describing the new cultivars and best bet production methods was circulated and provided to zonal communications officers for conversion into extension materials.

Throughout the project seed multiplication of the lines and cultivars being evaluated on-farm was undertaken at Ilonga using necessary isolation distances and plot rouging to maintain pure lines. Foundation seed was maintained of P9405 and P9406 and breeders seed of both lines was produced for subsequent distribution to selected seed multiplication sites in 2003.

In addition to on-farm work with the “advanced” lines screening continued of breeders’ lines studied by R6654. Seven lines, previously selected from field screening of 140 progenies ex ICRISAT Sorghum and Millets Improvement Programme, were evaluated in pot trials at Ilonga (for reaction to *S. asiatica*) and in replicated plots the field at Melela (*S. asiatica* and *S. forbesii*) in 2000.

Output 2. Predictive tool for assessing Striga tolerant sorghum cultivar x soil fertility interactions developed and evaluated: Field and laboratory studies were undertaken to develop practical guidelines for research and extension on how to target the use of available sorghum varieties based on a knowledge of soil fertility and the *Striga* tolerance or susceptibility of each variety. These involved a number of steps. Initially farmers participated in identifying the types of soils on which sorghum is most commonly grown in Central and Lake Zone. A study of farmer access and perceptions of soils was completed by interview and questionnaire and full chemical analysis of selected sites was carried out. Soils were analysed in the laboratories at ARI Mlingano. Detailed studies of the response of a P9405, P9406, Macia and Pato to *Striga* at levels of N typical of farmer fields identified in Central and Lake Zones were undertaken using the rhizatron system at University of Sheffield. The on-farm variety trials described under output 1 were undertaken on a range of identified soil types and soil and plant material were sampled for analysis to determine N uptake and use by different lines. Full details of methods are given in project working papers (Lamboll *et al*., 2001; Pierce, *et al*., 2002; Pierce *et al*., 2003). The results led to the development of decision tress designed to guide the choice of cultivar for use on different soil types and under different levels of soil fertility management. Drafts were presented to extension officers at the end of project workshops in March 2003 and modifications made on the basis of discussions that followed.

Output 3. Integrated management options for production of Striga tolerant sorghum cultivars validated by farmers: On-farm trials initiated by R6654 to validate integrated management options for production of *Striga* tolerant sorghum varieties continued in Central and Lake Zone villages. Two practices, inter-cropping with a legume or use of kraal manure, were examined. Inter-crops were planted in Mwagala, Iteja and Mvumi. Pure stands of sorghum cultivar Pato and P9405 were compared with plots inter-cropped with cowpea (cultivar Tumaini) in Lake Zone and groundnut (cultivar Nyota) in Mvumi. The legumes were planted in the same row as sorghum. Kraal manure was applied at either 0.25 or 0.5 kg per sorghum, planting station on a range of soil types in Mwagala, Iteja, Mpalanga and Chipanga. In 2000 manure use was evaluated with P9405, P9406, Weijita, SRN39, Pato and Macia. In 2001 P9405 was used. Inter-cropped and manure plots were planted at 5 farms in each village, with farms used as replicates. Data was collected on *Striga* emergence and sorghum yield. Group discussions were used to evaluate farmers' perceptions of the trials.

Output 4. Approaches which facilitate farmer and other stakeholder understanding of *Striga* and *Striga* management options developed and evaluated: The aim of work under this output was to develop guidelines on approaches which facilitate farmer and other stakeholder understanding of *Striga* and *Striga* management options. Studies in Chipanga and Mvumi were conducted by a post-graduate student from SUA and written up as a MSc. thesis. The value to farmers of a range of learning tools including a simple rhizatron, pot grown sorghum/*Striga*, field plots, posters, leaflets etc was examined through group discussions with project participants.

Output 5. Striga tolerant maize cultivars based on known traits identified: Studies for this output aimed to identify traits in maize that confer tolerance to *Striga*. If identified, selected *Striga* tolerant maize varieties would be proposed to Zonal programmes for further field testing. Initially a group of maize lines from Tanzania and IITA were evaluated in the field for reaction to *Striga* at Mwele seed farm (hotspot for *S. asiatica*) and Melela (hotspot for *S. forbesii* and *S. asiatica*). The trial included 8 early and 12 late/intermediate maturity open pollinated lines. Promising lines were then studied at University of Sheffield using the rhizatron system to allow the performance of individual plants to be monitored when infected under controlled conditions. Patterns of *Striga* germination stimulant production were also investigated. Full methods are given in Pierce *et al.*, (2002).

Output 6. *Striga* management options for upland rice developed and evaluated: Six upland rice lines were obtained from West Africa Rice Development Association. These had been developed in a programme aimed at introducing resistance to *Striga* into elite cultivars. Parental lines resistant to *S. aspera* and *S. hermonthica* had been selected by a previous CPP project (R5228, Johnson, *et al.*, 2000). Only limited seed was available so these were planted in plots of three rows, each 3 m long, at one site in each of Itope and Kilisilo villages in Kyela. Two replicate plots were planted at each site in 2001/02 and 2002/03. Fieldwork in Kyela focused on increasing the productivity of upland rice on *S. asiatica* infested land by improving soil fertility, specifically by raising N availability to the crop. In 2000 and in 2001 10 farmers in each village planted plots to evaluate the effect of urea applications (0, 25 and 50 kg N ha^{-1}) on rice performance and *Striga* infestation. The green manure *Crotalaria ochroleuca* (marejea) was introduced to the two farmer groups in 2000 and small demonstration plots were planted at 5 sites. One farmer test cropped this with rice the following year. Having observed considerable improvement in rice vigor and yield ten groups decided to stop trials with fertiliser and to concentrate instead on marejea. Seed was distributed to 30 farmers in 2002 for planting areas that would subsequently be test cropped with rice in 2003.

Review of *Striga* research needs in Uganda and proposal for CPP funding: CPP management requested that the project leader, Dr Riches, should visit Serere Agricultural and Animal Research Institute (SAARI) in Uganda to assess *Striga* research needs. Possible research output and activities were to be designed and proposed to CPP for funding if appropriate. The visit, undertaken in December 2000, involved discussions with key staff at SAARI, farm visits in surrounding districts and a review of previous and on-going relevant work.

Validation of findings CPP review of crop protection issues in semi-arid areas: In addition to this research on *Striga* in Tanzania the Crop Protection Programme has supported work on a number of crop protection issues in semi-arid areas of East Africa. The programme undertook a review of this work during 2002/03, as a means of identifying opportunities for future promotion and research relating to a cluster of projects on cereals in the region. The overall aim of the review was to assess the role and contribution of cropping to people’s livelihoods in semi-arid E. Africa and identify the implications for CPP promotional opportunities and emerging research opportunities to address poverty. One day was added to workshops, held to disseminate the findings of R7564, in order to discuss the findings of the CPP semi-arid review with stakeholders in Lake and Central Zones of Tanzania. The workshops were held at Ukiriguru and in Dodoma in March 2003.

Output 1. *Striga* tolerant sorghum cultivars validated by farmers and promoted to uptake pathways.

Field evaluations of sorghum lines

Findings from farmer evaluation of sorghum lines in on-farm trials in Central and Lake zones have been extensively reported and disseminated in Tanzania. Annual data summaries have been reported in project working papers (Mbwaga and Riches, 2000; Mbwaga, 2001 and Mbwaga 2002). Key findings were also presented to extension workers and NGO staff at the end of project workshops in March 2003. Typical results from on-farm trials are shown in Table 1. These should be viewed in conjunction with results from the series of on-station replicated trials (Tables 2-4) undertaken for the purpose of cultivar registration. It was consistently observed that lines P9405 and P9406 supported lower numbers of emerged *S. asiatica, S. forbesii* and *S. hermonthica* than other lines, particularly the released cultivar Pato. The "P" lines also tended to be more productive, producing higher yield than Pato and Macia at heavily infested sites. Pato and Macia on the other hand have a higher yield potential and perform well under *Striga* free conditions, as was observed at Ilonga. Infestation levels of a number of diseases were also recorded (see Mbwaga, 2003, paper C in workshop proceedings). P9405, P9405 and Macia are not susceptible to leaf blight that was a particular problem on Pato at a number of locations in 2002. P9406 is somewhat more susceptible than other lines to long smut so it would be better to plant P9405 on *Striga* infested fields in areas where long smut is common. All lines tested proved to be highly susceptible to sorghum midge. Indeed this proved to be a serious pest at Ukiriguru and Lake zone village sites when ever sorghum was planted late (after ± mid-February) during the long rains. Farmers' experience is that when the short rains are reliable, midge can be avoided by planting sorghum in this season. Midge remains an unresolved crop protection problem on sorghum.

Farmer ranking of sorghum lines

Farmers ranked the sorghums under test on their fields over two seasons according to their own criteria. These perceptions, based on farmers' own criteria, have been presented in detail in Lamboll *et al*. 2000 and 2001. Examples of these perceptions are shown in Tables 5 and 6. P9405 and P9406 ranked highly for a number of important traits including drought and *Striga* tolerance, early maturity and yield. The final ranking exercise was conducted in Chipanga in 2002 by which time some farmers had grown the new lines for four years. In a pair-wise ranking women ranked Macia first followed by P9405, Pato, and local landraces Lugugu and Mtika. The most significant change from the previous year's evaluation was that modern varieties were overall ranked more highly. Macia appears to be particularly favoured by women for its early maturity and yield and to some aspects of the *ugali* it produces. P9405 is perceived by women to have a higher yield and better tasting *ugali* than P9406. Men have consistently ranked the modern, shorter duration varieties more highly than the tall landraces over the two years that this exercise was carried out. Through pair-wise ranking P9405 has been ranked first in both years. Preference for the modern varieties according to men is based on earlier maturity, higher yields and more drought tolerance than tall landraces.

The ranking according to farmers criteria (Table 7) draws out some of the reasons why a range of sorghum types continue to be grown. Macia is ranked first overall with high yield, early maturity, drought tolerance and ease of marketing as important contributory factors. However, the variety is ranked relatively lowly according to post-harvest criteria such as the ‘heaviness’ and the taste of the *ugali*. Lugugu is ranked second overall and performs well according to almost all the post-harvest criteria, but very low against yield, maturity and drought tolerance. Interestingly though Lugugu appears to have a greater ability to recover if rains come after drought compared to modern varieties. P9405 performs well according to *Striga* tolerance, drought tolerance, yield and it makes good *ugali*. However, it performs less well in terms of the colour of the *ugali* and suitability for selling. P9406 is ranked highly according to *Striga* and drought tolerance, as well as early maturity. However, according to various indicators it is ranked relatively low in terms of making *ugali*.

Many farmers have adopted Pato due to its high yielding ability and relatively early maturity. However under conditions of drought, *Striga* and foliar disease, the productive potential of Pato is not realised. In such situations P9405 and P9406 offer alternative options and have been ranked by farmers as early maturing, *Striga* and drought resistant. Some local cultivars, although highly palatable, are late maturing and low yielding. Farmer assessment indicates that P9405 and P9406 are palatable and have a potential to be marketed. Macia is also liked by farmers and is intermediate between the P lines and Pato in it’s performance on *Striga* infested land.

The initial adoption of lines distributed to farmers for trials in Central Zone villages was investigated in early 2003 in a study of cultivar diffusion patterns (see Mwanga, 2003 paper D1 in the final workshop report). Over the past four years, 67 farmers had received seed from the project. In the first and second season few non-participants became interested in the varieties Macia, P9405 and P9406. However in the third and fourth seasons there was an increase in the number of farmers demanding the seeds. Following the 2001 harvest participating farmers reported retaining an average of 2.9, 3.6, 6 and 6.6 kg respectively of P9405, P9406, Pato and Macia as seed for the following season indicating their requirement for a diversity of cultivars. The average number of non-project farmers reported by each participant to have taken seed of modern short duration cultivars from them was 3.1 (P9405), 2.8 (P9406), 2.3 (Pato), while 4.1 received Macia.

Cultivar registration, multiplication and distribution

As a result of this work the findings were presented to the Tanzania Official Seed Certification Agency (TOSCA) in November 2002. TOSCA agreed to the registration and release of P9405 as the cultivar “Hakika” (meaning to be sure) and P9406 as Wahi (meaning early). The report to TOSCA justifying the registration of these cultivars (Mbwaga *et al*., 2002) can be found in Annex 1. The multi-location trials were inspected by TOSCA officials and cultivar was awarded a certificate of “Distinctness and Uniformity”.

The project produced 300 kg of each cultivar in 2002 under isolation at Ilonga where breeders’ seed will be maintained. This was passed to the government run Simba Seed Farm for production of foundation seed during the 2003 season. Seed was also given to the Missungwi district Extension Team that undertakes seed multiplication with the community and additional seed was also distributed to farmers in Mvumi and Chipanga.

Efforts were made to identify options for on-going multiplication and distribution of seed of the new cultivars. A policy of facilitating the availability of “Quality Declared Seed” has been adopted by the Ministry of Agriculture and Food Security in an attempt to ensure farmers can access uniform quality crop seed, without the need expensive certification procedures. Saadan (2003) described the role of QDS, and how it operates at community level – see paper D in final workshop proceedings. Three community seed supply strategies have been identified by a recent project, also working in Dodoma (Rohrbach *et al.,* 2002). In the "On-farm seed production programme" two farmers per village are trained and supervised by district extension authorities, TOSCA and the MAFS seed Unit to produce seed on behalf of the community. ICRISAT has supported a "Primary School Seed Multiplication Programme". Under this initiative seed is produced on the primary school plot for sale to neighboring farmers. Seed production is integrated into the school curriculum. The final option is the "Sustainable seed multiplication Programme" initiated by the Diocese of Central Tanganyika in 1995. Groups of 15 to 35 farmers are encouraged to collaborate in seed production on block of land isolated from other fields. Technical support has been provided by extension agents and farmers. These three approaches have all been successful in producing seed but Rohrbach *et al.*, 2002) conclude that none of the programmes is likely to continue without external technical support and funding. The issue of seed, and how to make Hakika and Wahi more widely available, was discussed by working groups at the end of project workshops. District extension staff and NGOs indicated that multiplication and distribution of the cultivars is now seen as a priority among future promotion activities in a number of districts. Groups that have undertaken local seed projects discussed the general lessons from these activities. As farmers usually save their own seed it is important to highlight the advantages of quality seed and to provide this at a reasonable price. It was generally agreed that technical support and training from TOSCA to support the QDS system will be essential and that there is a need to treat planting seed and to market this in small packets, clearly labeled as quality declared seed. Participants agreed that overall responsibility for initiating seed programmes lies with the districts. There are already a number of partnerships with NGOs which can be built on to scale up availability and distribution of Hakika and Wahi when foundation seed is available. The mechanisms used will depend on these existing partnerships and local circumstances.

Table 1. Performance of sorghum cultivars and lines in on-farm trials - means for 5 sets of village trials in 2001 and 2002. *Striga* number m^{-2} and grain yield t ha^{-1}.

Entry	Village/year									
	Mpalanga 01		Chipanga 01		Mvumi 01		Mvumi 02		Mwagala 02	
	Striga	Yield	*Striga*	Yield	*Striga*	Yield	*Striga*	Yield	*Striga*	Yield
P9505	2.9	1.4	0	1.6	2.27	0.60	5.75	2.0	2.27	0.60
P9406	20.3	1.1	0	1.0	1.09	0.78	0.82	1.4	1.09	0.78
SRN39	18.9	1.2	0.32	1.6	-	-	-	-	-	-
Macia	23.1	1.1	0.64	1.4	2.79	0.44	11.07	1.1	2.79	0.44
Pato	61.4	0.6	4.0	1.5	7.70	0.34	31.07	0.8	7.70	0.34
S.E.	3.8	0.05	0.61	0.11	0.93	0.12	6.55	0.96	0.93	0.12

Table 2: Multi-location evaluation of sorghum lines, 2000. *Striga* number per 7.5 m^2 at harvest and sorghum grain yield Kg ha^{-1}. Ilonga is a *Striga* free site.

Entry	Melela			Hombolo		Ukiriguru			Ilonga
	S. asiatica	*S. forbesii*	Kg ha^{-1}	*S. asiatica*	Kg ha^{-1}	*S. asiatica*	*S. hermonthica*	Kg ha^{-1}	Kg ha^{-1}
P9405	21.3	3.5	1700	99.5	1013	26.8	42.8	783	2300
P9406	16.8	8.0	2000	127	567	27.0	9.8	583	1800
SRN 39	114.0	55.5	1600	235	340	9.8	77.5	87	2200
Weijita	117.3	29.5	1600	98.5	420	8.3	122.0	60	3300
Macia	216.8	29.8	1100	149.5	846	6.3	60.0	283	2100
Pato	190.0	17.5	1200	161.8	527	14.3	62.3	233	3200
S.E.	28.3	5.9	90	18.18	108	5.17	11.11	58.7	140

Table 3: Multi-location evaluation of sorghum lines, 2001. *Striga* number per 7.5 m^2 at harvest and sorghum grain yield Kg ha^{-1}. Ilonga is a *Striga* free site.

Entry	Melela[1]			Hombolo		Ukiriguru			Ilonga
	S. asiatica	*S. forbesii*	Kg ha^{-1}	*S. asiatica*	Kg ha^{-1}	*S. asiatica*	*S. hermonthica*	Kg ha^{-1}	Kg ha^{-1}
P9405	2.3	3.3	1900	2.0	453	36.5	2.0	0[2]	2000
P9406	3.5	4.3	2000	7.5	400	32.8	0.0	0	3100
SRN 39	111.3	107.5	900	23.8	180	43.3	2.5	0	3600
Weijita	218.5	61.5	1200	12.0	147	65.3	2.0	0	4300
Macia	263	83.3	1100	19.0	367	35.5	11.3	0	3200
Pato	243	75.3	1400	92.3	107	41.8	3.5	0	4400
S.E.	31.56	11.77	120	8.14	38.0	3.77	1.29	0	240

[1] *Striga* counts at 12 weeks after planting
[2] No grain was harvested at Ukiriguru due to sorghum midge infestation following late planting.

Table 4: Multi-location evaluation of sorghum lines, 2002. *Striga* number per 7.5 m^2 at harvest and sorghum grain yield Kg ha^{-1}. Ilonga is a *Striga* free site.

Entry	Melela[1]			Hombolo		Ukiriguru		Ilonga
	S. asiatica	*S. forbesii*	Kg ha^{-1}	*S. asiatica*	Kg ha^{-1}	*S. hermonthica*	Kg ha^{-1}	Kg ha^{-1}
P9405	0.5	0	1900	25	2000	47.3	933	3200
P9406	0.5	0.3	1200	41	1600	14.0	943	3200
SRN 39	1.0	0.8	2500	169	800	48.0	890	3900
Weijita	67.3	40.8	900	141	700	19.5	953	2700
Macia	24.0	10.3	1300	71	1100	35.0	963	4000
Pato	75.0	4.8	1500	105	900	9.0	823	3700
S.E.	14.01	6.26	200	15.2	150	7.6	55.3	110

[1] *Striga* count at 12 weeks after planting

Table 5: Sorghum variety preference by farmers criteria: men and women in Mvumi Makulu village Dodoma rural

	Criteria	Tege meo	Mhuputa	Sandala	Pato	Lugugu	*P9406*	*P9405*	Bangala	Lugugu Arusha
1	High yielding	4	8	5	1	9	2	3	7	6
2	Ability to withstand drought	4	7	5	3	9	1	1	8	6
3	Ability to withstand Striga	4	9	5	3	8	2	1	7	6
4	Shortness of plants	3	7	5	4	9	2	1	8	6
5	Ease of marketing	9	6	3	5	1	6	5	4	2
6	Resistance to birds	6	-	5	7	2	8	9	1	4
7	Not easily attacked by field pests	6	3	5	9	1	7	8	3	4
8	Not shattering	4	2	5	3	8	2	1	7	6
9	Resistance to storage pests	9	9	6	5	1	7	8	4	3
10	Good tasting of ugali	9	2	7	8	1	6	5	4	2
	Total	58	56	51	48	49	43	42	53	45
	Ranking according to criteria	**9**	**8**	**6**	**4**	**5**	**2**	**1**	**3**	**7**

Table 6: Sorghum variety ranking by farmers criteria: Women in Iteja village Missungwi district.

No.	Criteria	Pato	Weijita	**P9406**	**P9405**	Macia	SRN 39	Mwnangund-ungu	Tegemeo	Mbapa-saba
1	Ability to withstand drought	7	9	3						
2	High yielding	4	6	3	2	1	4	5	6	8
3	Early maturing	5	9	3	2	1	4	8	6	7
4	Ability to withstand Striga	5	9	3	2	1	4	6	7	8
5	Diseases/pest tolerance	7	9	3	2	1	4	6	5	8
6	Easy of dehulling	1	3	-	-	-	3	3	2	3
7	Good taste	3	7	5	2	1	6	8	4	9
8	Marketability	1	8	5	4	3	9	6	2	7
9	Whiteness of grain	3	9	5	4	2	6	7	1	8
10	Ease of threshing	1	2	6	5	3	9	8	4	6
	Total	37	71	36	23	13	49	57	37	64
	Ranking	**4**	**9**	**3**	**2**	**1**	**6**	**7**	**4**	**8**

Table 7. Ranking of sorghum varieties by Men and Women in Chipanga, Dodoma in 2002.

	Serena	Mgali	Masiga	Ulezi	P9406	Sandala	SRN39	Chingwala	Pato	Lugugu	Mtika	P5	Macia
Ability to recover from drought	13	8	4	6	10	5	7	3	9	1	2	12	11
High yield	5	10	4	8	7	6	9	12	1	13	11	3	2
Early maturity	11	12	13	7	1	5	3	8	4	10	9	6	2
Ease of dehulling	10	8	11	12	3	6	5	7	9	2	13	4	1
Provides white flour	13	10	6	12	5	2	8	9	11	1	7	4	3
Little *pumba* (husk/chaff)	13	4	9	10	8	5	11	3	6	1	2	12	7
Whiteness of *Ugali*	13	10	4	12	8	2	7	5	11	1	3	9	6
Good *Ugali*	13	11	7	12	8	3	9	6	10	1	2	4	5
'Heaviness' of *Ugali*	11	5	8	13	7	4	12	3	10	1	2	6	9
Taste of *Ugali*	13	9	4	12	6	8	11	3	10	1	2	5	7
Suitability for local brew *pombe*	13	6	10	2	3	8	4	12	1	9	11	7	5
Suitability for selling	13	8	7	3	5	12	10	6	4	2	11	9	1
Ability to withstand Striga	12	11	9	6	2	4	5	8	13	10	7	1	3
Ability to withstand drought	5	10	11	6	3	8	7	12	4	13	9	2	1

Output 2. Predictive tool for assessing Striga tolerant sorghum cultivar x soil fertility interactions developed and evaluated

A number of complementary studies were undertaken to identify the relationship between soil nitrogen status, and nitrogen additions with particular reference to local soil conditions and specific cultivars. By a combination of laboratory and field work, supported by an investigation of farmers' perceptions of soil fertility issues, guidance developed on the deployment of new cultivars in Tanzania in the form of a decision support tool, was developed.

Farmer access to and perception of soils in Central and Lake Zone

Wealth ranking was carried out in each of the villages as an initial separate exercise. Details of the methods are given in Appendix 1. Four wealth groups were identified with the majority of households falling into the two least well off groups. A number of criteria are used by farmers to assess household wealth and these vary in importance from area to area. Cattle have traditionally been an important indicator. Access to cattle for ploughing is a key factor in soil management in Lake Zone, whereas in Central Zone there is very little use of draught animal power. Hiring in of labour and selling of labour are however generally applicable indicators. At least 30% of households in the two least well off categories hired out household labour and in the case of the least well off group in Chipanga 74% of households hired out their labour. Availability of labour is a key factor determining farmer decision-making in relation to soils and crop management. Generally, the better off households are more food secure. In good years (essentially related to rainfall) households in all wealth groups appear to achieve actual or close to food security. In Lake Zone many farmers reported a surplus equivalent to many months food. In bad years all wealth groups in almost all villages appear to have insufficient food. Chipanga appears to have the worst problems. Non-farm income is important across most wealth groups in the four villages. In the two Central zone villages non-farm earnings represent a higher proportion of income for the less well of groups. Remittances were frequently reported by the poorer groups, but also by some households in the better off groups. Access to land was reported as an indicator wealth and, in general, better off households have access to more land than less well off households. Interestingly, in three of the four villages households in the second wealthiest group appear to have access to most land. Perhaps surprisingly households in Central Zone had on average access to less land than those in Lake Zone. So the less well off groups in Mvumi Makulu and Chipanga are the households with access to least land, 0.9 acres and 3.3 acres per household respectively. This is closely related to food security. Households have gained access to land largely by inheritance. Significant quantities of land have been acquired by purchase while gifts are also important.

Estimates of the proportion of fields infested by *Striga* varied from 39% in Chipanga to over 60% in Mvumi and Mwagala. Farmers are well aware that *Striga* is associated with low and declining soil fertility. However, the majority of households contacted for the survey – ranging from 49% in Chipanga to 80% in Mvumi have never applied manure to cereal fields. The proportions using manure in each wealth category are reasonably similar. Carts are few and far between in the study villages so manure must be carried to the fields in baskets. Although richer households that hire more labour may be expected to use manure more than poorer households this does not seem to be the case.

Farmer classification and perceptions of soils has been reported for each study village in a project working paper (Lamboll *et al.*, 2001). In Central zone farmers consider *Isawawa (Isanga) chitope and nkhuluhi* as most suitable for sorghum production. *Striga* infests both. There has been a long history of work on soils in Sukumaland so there terms used to describe major soil types are well documented. There are also widely used by farmers. Sorghum is grown on the black *mbuga* soils of the valley bottoms. Although these are associated with high fertility and good moisture holding capacity they are heavily infested by *S. hermonthica. Striga* also infests sorghum on what are sandy *luseni* soils that are recognised to be low in fertility, *Ibusi* and *Itogolo* soils.

Characterisation of soils at benchmark sites

For any decision tool to be useful, it must be possible to interpret it in a localized context. Representative samples of the soils used by farmers for growing sorghum were therefore collected. Soil chemical analysis was undertaken at Mlingano ARI. Details of this chemical characterisation will be found in a project working paper in annex 1(Pierce *et al.,* 2003). All the soils analysed are poor in terms of nitrogen. (N) as shown in Tables 8 and 9. A low carbon/nitrogen ration indicates that the quality of the organic component is generally good although the absolute amount of soil organic carbon (C) was low to moderate in all cases. There is considerable agreement between farmers perceptions and the laboratory analysis. For example in Lake zone, the *mbuga* soils were identified by farmers as the most productive. Indeed this soil has the highest N, C and available phosphorus (P) content of any soil in the region. The productivity of the sandy *luseni* soils, is known to be poor. These have particularly low C, N, Ca and K contents, low cation exchange capacity and P availability (Table 8).

Laboratory assessment of tolerant sorghum cultivar x soil nitrogen interactions

Full details of the growth and photosynthetic response of Hakika, Wahi, Macia and Wahi to nitrogen availability and infection by *Striga hermonthica* when grown in sand culture under controlled conditions have been presented in two working papers (Pierce *et al.* 2002; Pierce *et al.*, 2003 – see Annex 1). Cultivars differed in susceptibility to *Striga*, using stem biomass as a sensitive indicator of response, with infected Pato exhibiting the greatest depression in stem biomass (84.8 % after 85 d) and P9406 showing the least depression (47.7 %) at higher N availability (Figure 3). Cultivars P9405 and Macia also showed greater tolerance than cv. Pato, with infected P9405 performing consistently well at all nitrogen availabilities. Depression in stem biomass was exacerbated by nutrient limitation (e.g. loss in stem biomass of 86.9 % for P9406 at 0.25 mM N). When uninfected, absolute biomass of Pato was much higher than the other cultivars (between 8.8 – 17.2 g higher for the nutrient treatments imposed), but when infected all cultivars attained equivalent total biomass at final harvest (i.e. ~17 g with 1 mM N). These results indicate that P9406 has the greatest tolerance of *Striga* at higher N availability's, with P9405 having the most consistent response to *Striga* infection where N supply is variable, in terms of losses in stem biomass on infection. Direct comparison of nutrient application in the field (doses of manure) and in rhizotrons (continuous through-flow of nutrient solution) is not possible. However, foliar N and P values in the lab were similar for the same cultivars grown in the field (i.e. a range of 8.5 – 20.8 mg N g^{-1} d.wt in the lab *c.* 19 – 24 mg N g^{-1} d.wt on luseni soil in the field; Pierce, Ley, Watling *et al*., unpublished data). Leaf phosphorus contents were also similar (2.1 – 4.4 mg P g^{-1} d.wt in the lab *c.* 1.6 – 4.2 mg P g^{-1} d.wt in the field), indicating that plants experienced equivalent nutrient availabilities. Indeed, foliar nutrient content, rather than availability to the roots, is perhaps most critical as N and P directly govern the amount of enzymes that are available to do work within the leaf, and thus metabolic constraints should be similar for field and lab-grown plants.

Figure 3. Pseudostem biomass of infected *Sorghum bicolor* (cultivars Pato, P9406, P9405 and Macia) as a proportion of uninfected control plants at 85 dap, under conditions of different nitrogen availability (0.25, 0.5 or 1.0 mM N as ammonium nitrate). Data represent the mean of six replicates. (Pierce *et al.,* 2002).

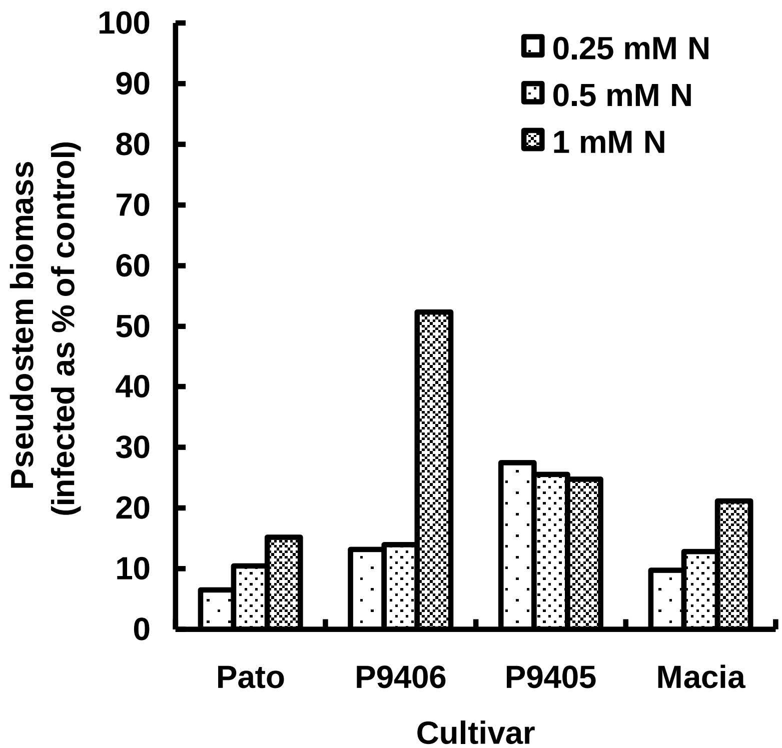


Table 8: Characteristics of major soil types recognised by farmers in the Lake zone.

Soil type		Chemical characteristics							
		pH (in KCl)	Organic C (%)	Total N (%)	C:N	Avail. P (mg kg^{-1})	CEC (meq. kg^{-1})	Ca (meq. kg^{-1})	K (meq. kg^{-1})
Lake Zone		Acid	Very low-medium	**V. low- low**	Good quality organic matter	Low-high	V. low-V. high	Medium-V. high	Low-V. high
Ibushi	Clay loams to clay, grey/black. Moderate productivity.	5.8 ±0.06	1.5 ±0.04	0.11 ±0.002	13.3 ±0.32	6.2 ±0.64	21.2 ±2.40	16.1 ±1.78	1.0 ±0.11
Itogolo	Dark grey sandy clay loam. Moderate/poor productivity.	5.6 ±0.05	1.1 ±0.04	0.09 ±0.002	11.6 ±0.24	1.0 ±0.03	11.7 ±0.45	9.7 ±0.60	0.7 ±0.02
Luseni	Sandy, Red in lowland, white in uplands, unproductive.	5.1 ±0.02	0.4 ±0.01	0.04 ±0.001	11.9 ±0.28	4.2 ±0.60	1.6 ±0.05	0.9 ±0.04	0.1 ±0.00
Mbuga	Dark grey/brown, clay or sandy clay. Very productive.	5.1 ±0.06	2.1 ±0.06	0.17 ±0.005	13.3 ±0.34	10.8 ±1.10	71.6 ±0.60	39.3 ±0.47	3.1 ±0.04

Table 9: Characteristics of the major soil types recognized by farmers in Central zone.

Soil type		Chemical characteristics							
		pH (in KCl)	Organic C (%)	Total N (%)	C:N	Avail. P (mg kg^{-1})	CEC (meq. kg^{-1})	Ca (meq. kg^{-1})	K (meq. kg^{-1})
Central Zone		Acid	Very low-medium	**V. low- low**	Good quality organic matter	Medium-high	V. low-low	Low-medium	V. low-medium
Isanga	Coarse loam, sandy, yellow. Sorghum grows well.	5.6 ±0.07	1.5 ±0.05	0.13 ±0.002	11.2 ±0.33	18.4 ±2.16	6.6 ±0.27	4.3 ±0.12	0.7 ±0.02
Isanga chitope	Sandy clay.	5.3 ±0.03	0.5 ±0.03	0.05 ±0.003	11.6 ±0.30	14.9 ±0.98	4.8 ±0.23	2.3 ±0.12	0.4 ±0.03
Ngogomba	Grey clayey soil.	6.6 ±0.03	0.9 ±0.04	0.10 ±0.003	9.4 ±0.21	22.1 ±0.46	1.1 ±0.14	0.6 ±0.09	0.2 ±0.03
Nkuluhi	Red sandy clay loam. Low productivity.	5.3 ±0.10	0.8 ±0.02	0.09 ±0.003	8.2 ±0.13	10.3 ±0.96	6.4 ±0.22	2.7 ±0.14	0.6 ±0.03

Validation of laboratory findings in field trials

Soil N was low (0.3 – 0.5 g kg^{-1}) and P availability very high (28 – 168 mg kg^{-1}) for *luseni* soil at the Ukiriguru field station, and yields were low, not exceeding 0.7 t ha^{-1} for heavily fertilised Wahi. Manure addition increased soil pH and N, leaf N and grain yields. However, soil available P, leaf and grain N & P contents were not consistently altered by manure addition. *Striga* was present throughout the plots, but was extremely abundant towards one end of the field and showed no consistent trend in relation to experimental treatments (see Table 5 in Pierce *et al*. 2003).

Table 10: *S. asiatica* infestation and grain yield of four sorghum cultivars grown with four soil nutrient treatments on Nkuluhi soil at Hombolo. (full data in Pierce *et al*., 2003). Urea applied at 50 kg N ha^{-1}.

Cultivar	**Fertility**	***Striga* at harvest m^{-2}**	**Yield t ha^{-1}**
Hakika	Control	5.7±4.17	1.8 ±0.30
	0.25 kg FYM	3.0 ±2.42	1.8 ±0.21
	0.5 kg FYM	1.0 ±0.41	2.1 ±0.09
	Urea	4.3 ±4.33	2.0 ±0.22
Macia	Control	42.5 ±30.71	0.9 ±0.36
	0.25 kg FYM	13.0 ±4.27	1.9 ±0.21
	0.5 kg FYM	7.1 ±3.23	1.6 ±0.19
	Urea	7.4 ±5.88	1.5 ±0.41
Pato	Control	49.0 ±29.23	1.0 ±0.30
	0.25 kg FYM	38.9 ±28.15	2.4 ±0.50
	0.5 kg FYM	11.1 ±4.34	2.5 ±0.07
	Urea	6.5 ±5.84	1.3 ±0.40
Wahi	Control	11.6 ±6.63	1.7 ±0.27
	0.25 kg FYM	14.3 ±12.59	2.3 ±0.40
	0.5 kg FYM	6.3 ±3.51	2.1 ±0.26
	Urea	7.0 ±6.78	1.8 ±0.20

At Hombolo field station FYM did result in decreased numbers of emerged *S. asiatica*, also increasing grain yields for all cultivars (Table 10). Urea was as effective as FYM at decreasing *Striga*, and yields were increased, but application of either 0.25 or 0.5 kg FYM resulted in the highest yields for all cultivars. Soil pH, N and also available P were increased by FYM addition, but urea did not increase soil N for soil supporting cultivars Hakika, Macia and Wahi. Similarly, leaf N content was increased by FYM but not by urea, indicating that extra N from urea was not present in the soil or plants towards the end of the experiment. Grain quality, in terms of Ca, Mg, N and P contents, was not altered by fertiliser treatments (see Table 6 in Pierce *et al*., 2003). Cultivar Pato had the highest yield when fertilised with 0.5 kg FYM (2.5 t ha^{-1}), but one of the lowest yields without fertilisation (along with Macia; 1.0 and 0.9 t ha^{-1}, respectively). Yields of Hakika and Wahi were consistently high, with 1.8 and 1.7 t ha^{-1}, respectively, in control plots, with up to 2.3 t ha^{-1} with added FYM (Table 10). When urea was used to fertilise plots, Hakika and Wahi had the highest yields (2.0 and 1.8 t ha^{-1}, respectively) and Pato the lowest (1.3 t ha^{-1}).

Addition of FYM to *luseni* soil on farm in Lake Zone increased pH, soil organic carbon, N, available P, CEC, Ca, Mg, K, Na and electrical conductivity (Pierce *et al.,* 2003 Table 2). Decreased C/N ratios with manure addition indicate an increased quality in the soil organic component. FYM applications of 0.5 kg/plant suppressed the emergence of *S. asiatica* and *S. hermonthica* on *luseni* soils (Pierce *et al.,* 2003 Table 3), although *S. asiatica* was more abundant on cultivar Pato when fertilised. *S. asiatica* was also more abundant on Pato when *nkuluhi* soils were fertilised in Central zone, with cultivars Hakika, Macia and Wahi supporting fewer *Striga* plants. Grain yields of all cultivars were higher here when fertilised (N.B. midge attack resulted in loss of grain yield on luseni soil), with Pato yielding the least grain (1.1 kg/plot) and Hakika yielding four times as much as Pato (4.5 kg/plot) and Macia and Wahi also yielding well. Hakika and Wahi also had particularly high yields when no fertiliser was applied (3.4 and 3.1 kg/plot, respectively).

Decision support tool

The high availability of phosphorus in unproductive sandy soils such as *luseni*, and increasing foliar nitrogen and yields in response to greater nitrogen availability, indicate that N is the limiting macronutrient for the growth of sorghum in the field on the soils investigate by the project. Both farmyard manure and urea suppress *Striga* when applied early in the growth season, when *Striga* attaches to host roots. However, when urea was applied to *nkuluhi* soil a lack of extra N was evident in the soil/plant system at the end of the growth season (*cf*. unfertilised controls). With relatively small or no increases in grain yields (*cf*. FYM) this indicates that urea was leached from the soil. Thus, heavy application of urea fertiliser to sandy soil with little organic carbon, in combination with high rainfall, could explain the observed losses of urea N. Extension workers in the Dodoma region of Tanzania report that farmers have found urea fertilisation to be very inconsistent (P. Lameck, pers. comm.).

Conversely, manure is rich in organic matter and will retain nitrogenous compounds for longer, in addition to containing other macro- and micro-nutrients such as Ca, K and P. It is technically possible to apply so much fertiliser that nitrogen becomes toxic to the plant. However sorghum growth and yields were highest at excessive manure application in the Ukiriguru trial, indicating that for the nutrient-poor agricultural soils of Tanzania the upper limit to manure application will be constrained more by economics than by toxicology. Possibly, supplementing urea with organic matter in the form of green manures may retain nitrogen in the soils and increase productivity. Low rates of urea application should also avert excessive leaching.

The sorghum cultivars investigated showed consistent responses to *Striga* and fertiliser both in the field and in the laboratory. The laboratory study showed that when supplied with sufficient nitrogen, cultivar Pato attained the greatest pseudostem biomass and height of the cultivars tested, but this was drastically curtailed by infection with *S. hermonthica* (i.e. Pato is heavily stunted). Wahi and Hakika, although smaller in stature, were not stunted to the same extent. Also, despite severe nitrogen limitation to growth at 0.25 mM N, cultivar Hakika retained the same degree of tolerance to *S. hermonthica* infection. Indeed, in the field Hakika and Wahi also showed grain yields equal to or far surpassing those of Pato and Macia when no nutrients were added to soils.

Thus, perhaps most importantly for the farmers who rely on sorghum in times of drought, Hakika in particular is relatively consistent (hence the name which in the Kiswahili language means 'certain' - Wahi means 'on time' due to its early flowering characteristics). Early flowering characteristics allow a greater likelihood of yielding should rains fail towards the end of the season, and if rain is plentiful an additional harvest may be achieved. Both the field and laboratory studies determined that cultivar Macia is intermediate between Pato and Wahi in its growth response to *Striga* and fertiliser, and provides another good choice for farmers who currently grow Pato. Pato may yield well and provide a good choice where soil fertility is particularly high or where *Striga* is absent.

These findings have been distilled into the following recommendations for farmers of Tanzanian soils:

1. Either manure or urea can be applied to young sorghum to suppress *Striga*.
2. Manure can be applied just once and will remain in the soil, and is recommended as a good all-round plant food.
3. Urea is not recommended as it is not an all-round plant food and is washed out of sandy soils; if used it should be reapplied in small amounts periodically.
4. Apply as much manure as can be acquired.
5. Hakika is recommended over other cultivars on extremely infertile and variable luseni and itogolo soils (Lake Zone) and isanga, isanga chitope, ngogomba and nkuluhi soils (Central Zone).
6. Wahi is recommended on more consistent, fertile mbuga and ibushi soils (Lake Zone), although Hakika and Macia are also good choices for these soils.

The decision trees presented in Figs. 4 and 5 represent guidelines for the implementation of these recommendations. These decision tools were identified by stakeholders at the end of project workshops as useful and easy to utilize in devising flexible, local recommendations. However, these decision trees are based only on the data presented here, and stakeholders identified a need to incorporate other factors that influence the growth of crops in future versions.

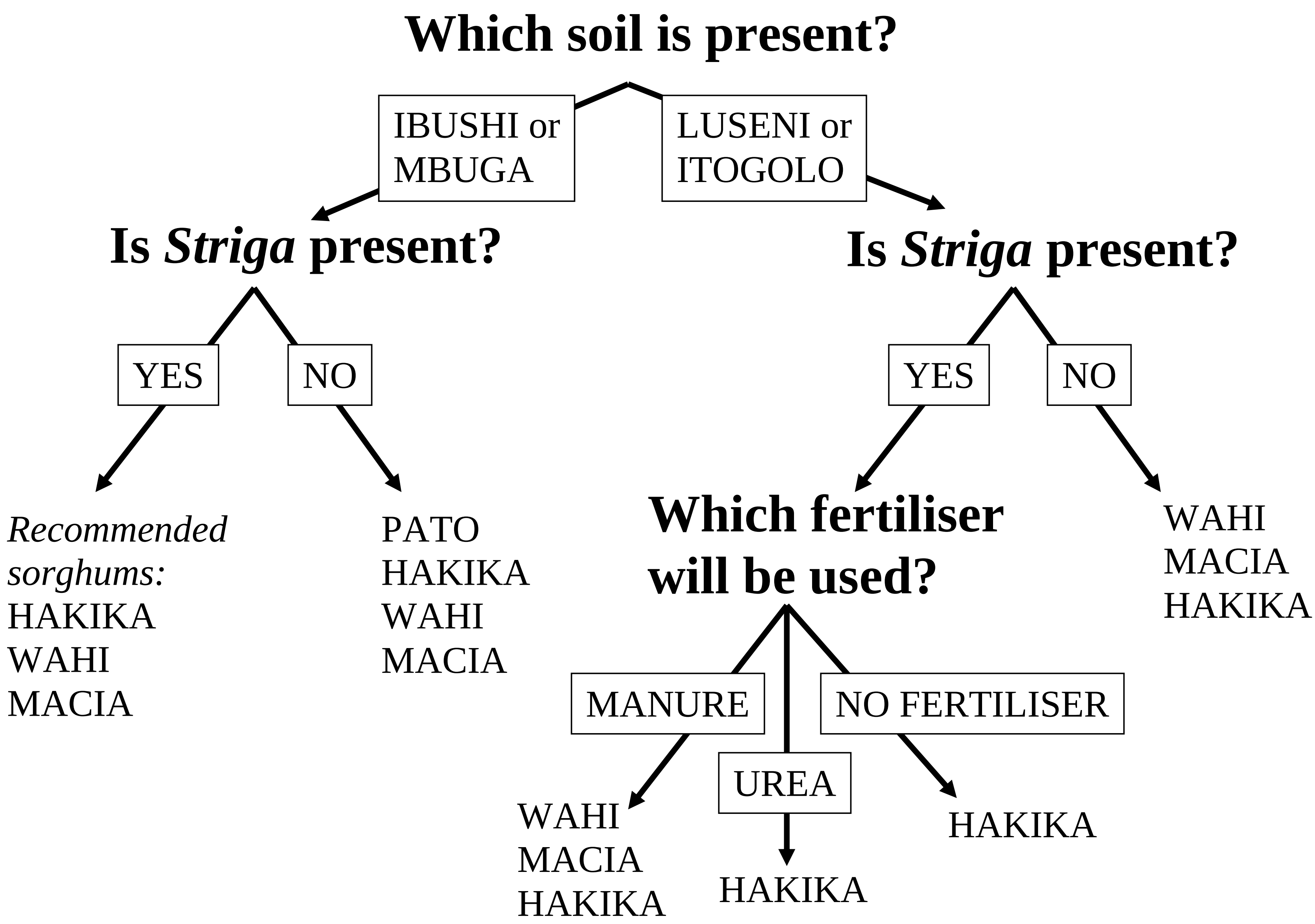


Figure. 4. Decision tree outlining the choices of sorghum cultivars recommended for growth on soils in the Lake Zone of Tanzania, based on data from the present study.

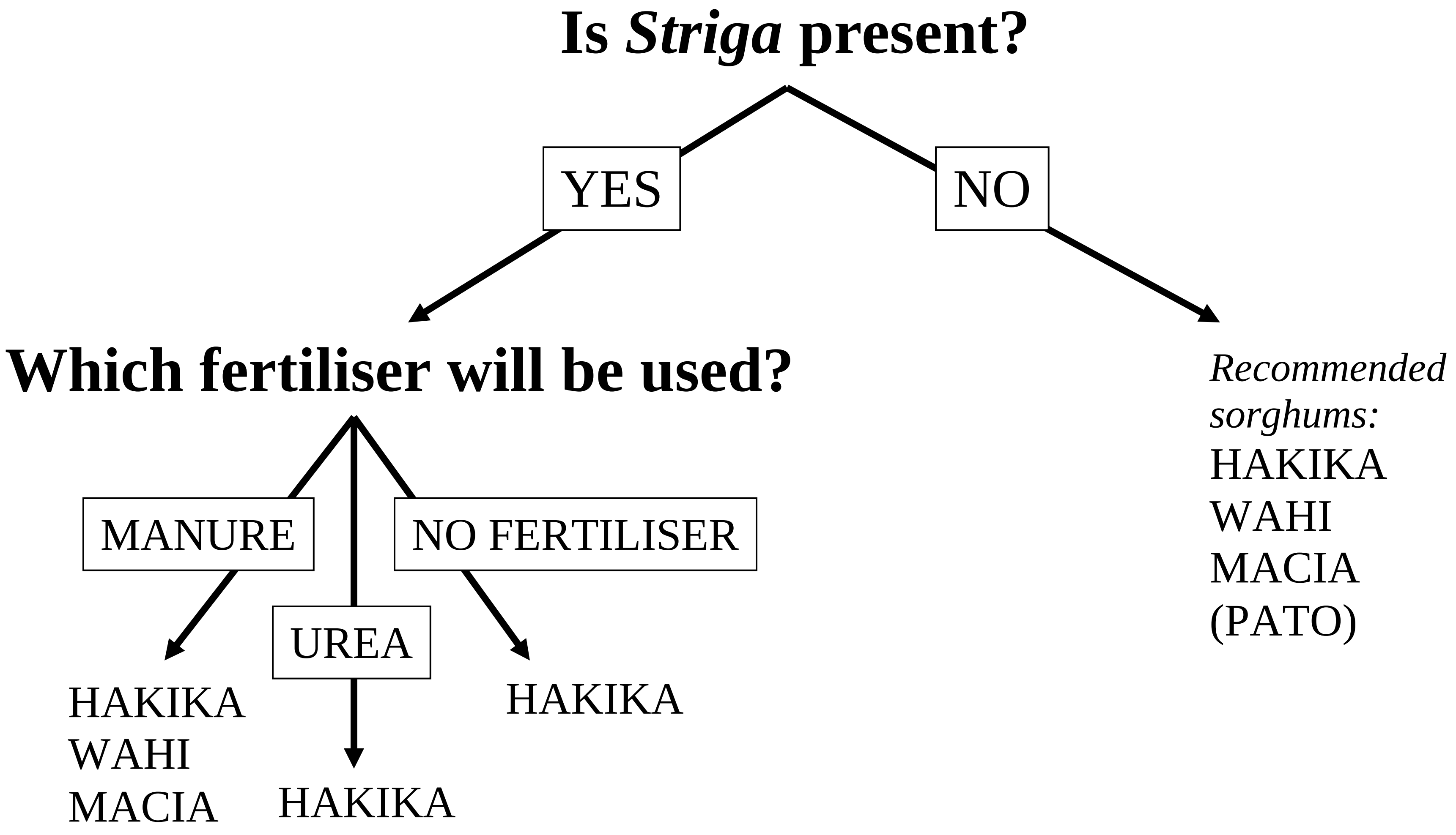


Figure. 5. Decision tree outlining the choices of sorghum cultivars recommended for growth on soils in the Central Zone of Tanzania, based on data from the present study.

Output 3. Integrated management options for production of Striga tolerant sorghum cultivars validated by farmers.

As a component of on-farm trials farmer groups evaluated the performance of short duration sorghums when fertiliser with kraal manure and when inter-cropped with legumes. The performance of sorghum under different levels of soil fertility has been discussed under output 2. Further data on trials with manure have been reported in Mbwaga and Riches (2000) and Mbwaga (2001).

Evaluation of use of manure application

As concluded earlier the extent to which farmers can use manure as a component of *Striga* management depends very much on availability, labour and transport. It has been pointed out that in the communities studied manure has been used by only 50% of households at best. Attitudes on using manure were discussed with farmers in Chipanga where there are significant numbers of cattle and local bylaws encourage the use of manure. The evaluation showed that both women and men associated manure application with increasing yields, but that this was only the case if there was sufficient rainfall and women reported that it was not true for all soil types (Table 11). When questioned further farmers conceded that it is only in drought years that increased yields are not realised when manure is used. As the climate is so unpredictable the general feeling was that it is better to use manure if it is available than to fore go that opportunity. Men reported that manure reduces *Striga.* Difficulties associated with manure application included an associated increase in weeds and pests. Increasing weed infestation where manure is applied is a common perception among smallholder farmers in sub-Saharan Africa and is related to the method of use, which is generally straight from the kraal. Men pointed out the work involved transporting manure to the fields.

Clearly not all farmers will be able to use manure but it remains a useful option. For increasing the yields of short duration sorghum cultivars on *Striga* infested soils.

Table 11. Perceptions of strengths and weaknesses of applying farm yard manure (Samadi) in Chipanga

	Strengths of using manure	Weaknesses of using manure
Women	• Large heads of sorghum are produced • *Nkuluhi* soil - if you put manure you get a higher yield • Groundnuts yield well if manure is applied	• Sorghum dries up if you put manure • On *Ngogomba* soil many pests emerge • *Ilolo* soil – if you apply manure you don't get a crop • *Kichanga* soil – when you apply manure you don't get a good yield when rainfall is low • Many weeds emerge when manure is applied
Men	• Higher yields if there is sufficient rainfall • *Striga* is reduced • Soil is made softer	• If rainfall is low crops dry quickly where manure has been applied • Weeds increase • Applying manure is a lot of work

Inter-cropping cereals with legumes

Sorghum was inter-cropped with groundnuts in Central zone villages and with cowpea in the Lake Zone. Legumes were planted in the same row as the cereal. Data for the 2000 season is shown in Tables 12 and 13. Inter-cropping generally reduced the number of emerged *Striga* stems visible by harvest. The legume affected sorghum productivity adversely in some cases particularly at Iteja. This effect was more in evidence the following season when inter-crop sorghum yields were approximately 50% of those from sole crops (see Section 4 in Mbwaga, 2001). Sorghum yields were low due to insect damage and drought periods during the season magnified the competitive effect of the inter-crop.

Table 12: Effect of inter-cropping sorghum with groundnut in on-farm trials in Central Zone in 2000. *Striga* per 25 m^2 and sorghum grain yield.

	Mvumi		**Hombolo**	
Treatment	***Striga***	**Yield kg ha^{-1}**	***Striga***	**Yield kg ha^{-1}**
Hakika + Groundnuts	118	1560	0	900
Hakika	140	1600	1	800
Pato + groundnuts	392	1440	25	1400
Pato	989	1200	360	600
S.E.	224	252		

Table 13: Effect of inter-cropping sorghum with cowpea in Lake Zone in 2000. *Striga* per 25 m^2 and sorghum grain yield.

	Mwagala		**Iteja**	
Treatment	***Striga***	**Yield kg ha^{-1}**	***Striga***	**Yield kg ha^{-1}**
Hakika + Cowpea	43	1400	0.5	1100
Hakika	50	2200	9.5	1400
Pato + Cowpea	31	2600	22.5	600
Pato	394	2200	61.5	1200
S.E.	76	400	10.7	130

Farmers recognise that inter-cropping has the advantage of providing more than one crop from the same piece of land (Table 14). Legume yields were difficult to assess in the trials as farmers harvested cowpea for use green vegetables and also tended to harvest groundnuts before they are mature. An evaluation of inter-cropping cereals and legumes was carried in Chipanga, where it is not a common practice. Women reported that a sorghum/groundnut inter-crop improves soil fertility and that sorghum yield will be high if there is sufficient space and if you weed early. A number of weaknesses were identified regarding inter-cropping of specific legumes with sorghum: bambara nut will not produce a yield (women), groundnut will not produce a yield (men) and cowpea will crowd out sorghum (men). Women considered that tall sorghum types were more appropriate for inter-cropping than short types.

Table 14. Perceptions of strengths and weaknesses of inter-cropping in Chipanga.

	Strength	Weaknesses
Women	• To get two crops in one area • Improves soil fertility (Sorghum and groundnuts) • Sorghum heads will be big if there sufficient space • Yield is higher if you plant groundnut and bambara nut • High yield if you weed early	• You don't get a yield from bambara if planted with sorghum, • The heads will be small if the space is small • Yield is low if you don't weed early • Crop stems become entwined • It depends on the type of sorghum short/ tall –tall is easier/ more suitable to inter-crop
Men	• You get many crops. • You get yield from two crops at one time	• If you plant cowpea and sorghum, cow pea crowds out the sorghum • If you plant sorghum and groundnut the same day, the groundnut will not yield-

Output 4. Approaches which facilitate farmer and other stakeholder understanding of *Striga* and *Striga* management options developed and evaluated.

Ensuring that farmers have a basic knowledge of *Striga* biology and it's attachment to the host crop has been a key component of interaction between the project, village extension officers and farmers. Farmers recognise that it is associated with fields where susceptible crops grow poorly and that the parasite is associated with poor fertility. Understanding the basic steps in the life cycle of *Striga* can empower farmers and other stakeholders to adopt appropriate control measures through understanding how and why they work. During group meeting farmers have often described themselves as "farmer-researchers" which provides an indication not only that they feel ownership of the work but that they also can use their understanding of the problem to search for solutions. This aspect of the project therefore evaluated a number of learning tools that it is hoped can be used by extension or NGO staff in the future to raise farmers awareness of the *Striga* problem and improve their understanding of how management practices work. These are largely knowledge intensive and often only make complete sense and can be understood in relation to key aspects of *Striga* biology.

A post-graduate student from SUA with some supervision from the project undertook work towards this output. Details of the methods and findings of this study, which was carried out in Mvumi and Chipanga, have been presented in a thesis to the university (Nyankweli, 2002). A summary of the study and the advantages of a range of learning tools that can be used with farmers and groups was also presented to the project final workshops (see Nyankweli, 2002 – paper F in the workshop report in Annex 1). The following were evaluated with farmers including members of the groups who had undertaken on-farm trials and non-participants:

- Portable rhizatron – this is a thin wooden framed box. It is filled with sand infested with *Striga* seed. Sorghum is planted into the sand and the development of *Striga* on the host roots may be viewed through a clear perspex cover. This system has been used at University of Sheffield to study the host-parasite association. Rhizatrons were set up with farmers and were looked after by village extension officers.
- Pots – sorghum and *Striga* were planted in pots. These can also be maintained by the VEO.

- Field trials – these have been in regular use in both villages by the project.
- Posters - in colour, showing the life cycle and control options, these have been used in village seminars by the project to increase farmer knowledge on *Striga*.
- Leaflets – two short leaflets in Swahili were examined. One was produced by Central Zone Information office and the other by NRI.
- Drama and song – used by a number of organisations and schools for community education e.g. for HIV/AIDS programmes
- Radio – there are agricultural programmes on local radio.

Table 15: Summary of ranking of learning tools by farmer group members and non-participants. 1= most preferred; 7 = least preferred.

Tools	Mvumi		Chipanga	
	FG members	Non-members	FG members	Non-members
Rhizatron	1	1	2	1
Pots	3	5	3	3
Posters	4	1	6	4
Leaflets	6	5	4	5
Radio	4	7	7	7
Drama & songs	7	1	5	6
Field trials	1	1	1	2

A summary of farmer rankings of the tools is shown in Table 15. Generally, both villages ranked the *Striga* trials and the rhiztron as useful learning tools for learning about *Striga* biology and options for management of the problem. Pot experiments were also ranked highly. These are provide a learning experience in which farmers and extension staff can participate to see how sorghum grows in the presence of *Striga*. Farmers appreciated the participatory nature of these approaches although each was perceived to have disadvantages (Table 16). In the case of field trials it was pointed out that only a few people might be involved. Although the project achieved a degree of ownership among the farmer research groups this was not apparently extended to the community. Demonstrations should be different and this finding indicated the need for careful discussion within the community to choose sites and ensure maximum participation in setting up plots and undertaking field visits and evaluations. The rhizatron was well received because the *Striga*/host association can be easily observed and understood. There was concern about local availability of materials. Extension staff at the end of project workshops discussed this at length. They were keen to have access to rhizatrons and suggested that they could be adapted to local conditions.

Written materials were less well received by farmers, partly due to concern that these are not readily accessible to illiterate people. The posters had been on display in village offices but this turned out to be a mistake. People associate visits to the village office with administrative or court business and do not find this conducive to receiving agricultural knowledge. Radio programmes are heard by many people but the listener can not se what is being described. Drama and songs may be entertaining but were not thought, on their own, to really provide sufficient information. This study suggests that a combination of learning tools is an ideal solution and should be used for scaling up the promotion of the findings of the project.

Group discussion sessions were held at the end of project workshops at which participants considered the potential for using a number of learning tools in future promotion programmes (see workshop reports, Lamboll *et al*, 2003). The sorghum cultivar-soil fertility decision tree was seen as cheap and straightforward with the potential for use on a large scale. The fact sheet on cultivars was appreciated as providing useful information although additional advice on other aspects of sorghum production should be added in future. These are both sources of information that will be useful to extension staff, who will need to be trained on their use. Of the learning tools aimed at farmers it was considered that a number should be used to compliment each other. Field plots were accepted as useful, although there was a concern over the cost of reaching many farmers. It was recognised that the audience for leaflets and posters will be limited by literacy. In conclusion district extension managers considered that these sources of information should be made available to VEOs through training courses so that they can be applied in day to day promotional activities and when advising the community on *Striga* management.

Table 16: Farmers perception on the advantages and disadvantages of learning tools used to increase knowledge of *Striga* biology and management.

TOOLS	Advantages	Disadvantages
Rhizotron	Show clearly what is happening underground and the interaction between Striga and crop roots. It is effective on transferring biological knowledge.	Not readily available and it is expensive. Cost of the glass
Field trials	- Participatory in nature -Experiential learning - More incentive i.e. free seeds	Segregation: only few people are involved
Pot experiment	Easier to prepare	Effect of *Striga* on roots can not be viewed
Posters	Pictures attract readers / viewers	It is not suitable for illiterate people
Leaflets	Easier to take at home and read anytime/ anywhere	It is not suitable for illiterate people
Drama and songs	Educate and entertaining	Not easy to keep memory / easier to forget
Radio	Heard by many people	Not practical: people don’t see actually what is happening

Output 5 Striga tolerant maize cultivars based on known traits identified

Field screening of maize

Full results of two seasons of field screening of maize lines at Melela and Mwele are presented in Mbwaga and Riches (2000) and Mbwaga (2001). Among the early maturing lines TZE Comp. $5C_6$ supported low number of emerged *S. asiatica* or *S. forbesii* and significantly out yielded the local check Staha at Melela in 2000. At Mwele, where there was low *Striga* emergence on Staha the check produced the highest yields. A number of late-maturing lines yielded as well as Staha at Mwele. IWD STR CO produced significantly more grain than the check and was among the lines with fewest emerged *Striga* at 12 weeks after planting. TZ 96 STR Syn White also supported few emerged *Striga*. In the short rain season at Mwele in 2000/01 the entries were planted on *Striga* infested soil and a plot cleared of *Striga* by using methyl bromide three years before. *Striga* counts were high (mean of 35.7 m^{-2}) among short duration lines but infestation was less intense (8.8 m^{-2}) on intermediate and late maturing materials. Yield loss due to *Striga* varied from 13% for the local check TMV-1 to over 60% for 98 Syn WEC. In the later maturity group yield loss ranged from less than 10% (TZL Comp $1C_4$, 9022-13, STR EV.IWD) to a high of 56% (TZ 96 STR Syn White). In the long rains yield loss was not determined. Low *Striga* numbers and high yields were associated with *Zea diploperennis* BC4C2, TZ 96 STR Syn White, TZ 96 STR Syn yellow, TZ Comp $1C_4$ and STR EV.IWD.

Identification of tolerance in the laboratory

Four early and four late maturing lines that had performed well in the field trial and the Tanzanian released cultivars Staha and TMV1 were selected for further study at the University of Sheffield. Observed in rhizotrons, *Striga asiatica* attached and developed on roots of all cultivars, indicating that none exhibited a true resistance mechanism (Pierce *et al*., 2003). However, root exudates from two cultivars, IWD STR Co and *Zea diploperennis* BC4C2, stimulated relatively little germination of *S. asiatica*, indicating low xenognosin production, with few parasites attaching and no significant decrease in host height or biomass apparent after 55 d of infection. Cultivar 98 Syn WEC also exhibited no significant differences in height or biomass on infection, despite high xenognosin production and a lack of resistance to parasite attachment and development, indicating the operation of a tolerance mechanism. There was also no significant difference in whole plant biomass between infected parasitised and uninfected plants for ACR 94 TZE Comp White, TZ96 STR Syn. White or the local cultivar Staha. These lines should now be evaluated by farmers on *Striga* infested fields.

Crossbreeding of the low xenognosin-producing and *Striga*-tolerant lines could produce cultivars that perform exceptionally well on *Striga*-infested soils by combining two mechanisms that allow the crop to perform well under infested conditions. This study highlights the need for maize breeders to distinguish between the different mechanisms underpinning host performance in the presence of *Striga*.

Output 6 *Striga* management options for upland rice developed and evaluated

Field screening of rice

A maximum of 9 *Striga* stems per plot of 3 rows emerged on the six lines of rice obtained from WARDA on the observation plots planted at Kilasilo and Itope in 2002 (see Mbwaga, 2002 for data). Unfortunately the individual plot yields were mixed after harvest preventing any assessment of the productivity of these introductions. These rice lines are however short stemmed compared to locally grown cultivars – farmers in Kyela panicle harvest rice and favour tall types for this reason. Sufficient seed had been held back in store to allow the trial to be repeated in 2003. In early May *Striga* on all entries with the exception of WAB 928-22-1-2-1B. The 2003 plots are being monitored by project R8194. Seed of any promising lines will be retained and grown on larger plots by the farmer group in Kilasilo in 2004.

Managing *Striga* in rice by increasing soil fertility

Striga infestation levels were low in 2001 (mean of 22.3 and 4.9 emerged stems per 25 m^2 at harvest in Itope and Kilasilo villages respectively). However trials investigating the use of urea on upland rice showed the same trend as in the past three seasons (Table 17; full results in Mbwaga, 2001). *Striga* emergence was greatest on unfertilised plots and declined with increasing

Table 17. Effect of urea on *Striga* emergence at harvest and grain yield of upland rice on 10 farms in each of two villages in Kyela District, 2000-01 season.

Urea kg ha^{-1}	Itope		Kilasilo	
	Striga per 25 m^2	Yield kg ha^{-1}	*Striga per 25 m^2*	Yield kg ha^{-1}
0	29.9	2100	7.0	2800
25	24.0	3400	5.4	3600
50	13.2	4400	2.3	4600
S.E.	10.13	240	1.1	330

dose of fertiliser. Yield increased substantially with increasing dose of urea and was on average 43% and 84% higher following application of 25 kg and 50 kg N ha^{-1} respectively. Over the four seasons that these trials have been conducted farmers concludes that urea reduces *Striga* infestation but does not eradicate it and that rice yields are considerable increased by fertiliser use. Survey data from the early 1990s (ICRA, 1994) indicated that inorganic fertiliser did not play a significant role in the cropping system in Kyela – only 56% of farmers had ever used fertiliser and of these 85% had either reduced application rates or stopped using it completely. Fertiliser use on upland rice is almost unknown among the farmer group members collaborating with the project. This is due entirely to the cost and lack of liquidity or affordable credit for the purchase of seasonal inputs. Although an IFAD project to make credit available had been launched by the district extension service, farmers do not favour the repayment conditions. The scheme required farmers to repay the loan at harvest when rice is worth about one third of it's value 4 to 5 months later. Farmers were therefore very interested in observing the plot of rice planted by one of the group members in Kilasilo following *Crotalaria* planted in 2000. The farmer estimated that he was able to harvest a similar yield to the plot on which he had applied 50 kg ha^{-1} urea. This observation stimulated farmer interest in using *Crotalaria* and this was planted at over 30 sites the following season. The performance of rice following *Crotalaria* is being monitored by project R8194 which has expanded the promotion of legume/rice rotations in Kyela. The project team visited a number of sites in May 2003 where farmers had planted rice after *Crotalaria*. The increased height, tillering and general vigour of rice, following *Crotalaria* was clear. Even where *Striga* had emerged, rice vigour was maintained and the effect of the parasite ameliorated. Participating farmers are already planning to expand the use of the green manure and other farmers are asking for seed. A number have planted separate areas for seed multiplication. In some cases these have been planted in the rice fields. Elsewhere farmers have experimented with undersowing the green manure into maize on home garden plots.

The potential of Crotalaria has been further demonstrated in research-managed trials undertaken by Juma Kayeke, PhD student from SUA who has been working with the project (Table 18). Rice yields were increased by 166% and 242% at two sites by including *Crotalaria* in the rotation and ploughing this under at flowering. Significant yield gains were also achieved by leaving the green manure biomass on the surface as mulch. In this situation land was prepared and planted by hoeing. Both systems are used in Kyela. These trials also confirmed that *Striga* incidence in rice is reduced by the rotation. This is to be expected as *Crotalaria* was shown by project R6654 to produce the *S. asiatica* germination stimulant (Riches, 1999). A further advantage of the *Crotalaria/*rice rotation, observed on the trials and experienced on a field scale by farmers is the effect of the green manure on weed infestation. Generally farmers need to weed upland rice at least twice. Following *Crotalaria* a number have only had to weed once and are very impressed by the labour saved due to the weed suppression achieved by growing the green manure for just one year.

Table 18. Effect of *Crotalaria* on *Striga* emergence at harvest and grain yield of the subsequent upland rice at two sites in Kyela District, 2002 season. *Striga* counts at 12 weeks after sowing $6m^{-2}$ $\sqrt{(x+0.5)}$.

System	Itope		Kilasilo	
	Striga per m^2	Yield kg ha^{-1}	*Striga per 25 m*^{2}	Yield kg ha^{-1}
Continuous rice	6.8	876	7.85	1018
*Crotalaria/*rice - incorporated	1.26	3000	1.76	2716
*Crotalaria/*rice - mulch	1.24	2483	2.28	2885
S.E.	0.18	95.08	0.34	95.2

Striga *research needs in Uganda and preparation of a proposal for CPP funding*

Dr Riches visited Serere Agricultural and Animal Research Institute (SAARI) in Uganda during December 2000 and met with staff at SAARI and visited farms in surrounding districts. Findings and recommendations were reported to CPP management (Riches, 2001 – annex 1). A set of research outputs with associ*ated activities, suitable for support by DFID funding was developed. These covered:*

- the identification of tolerant/resistant cultivars of sorghum, finger millet and upland rice;
- the identification and farmer evaluation of cultural Striga management strategies.

Following previous work in Uganda and Tanzania a number of promising sorghum lines were identified and it was recommended that these should tested in participatory variety selection trials on-farmers fields in districts adjacent to Serere. It was also recommended that on-farm work should also be initiated on rotations and inter-crops including cotton, once an important crop in local systems.

The review concluded that these on-farm studies should be proposed for support by the DFID funded Client Oriented Agricultural Research Fund (COARF), based at SAARI. Other more strategic work on the identification of resistant finger millet and rice lines and the use of the weed *Celosia argentia* for *Striga* suppression would have potential benefits elsewhere in East Africa also and it was recommended that the Crop Protection programme should consider funding this. The proposed outputs and activities on sorghum systems were subsequently included in a successful project proposal submitted to COARF. The project "Evaluation and promotion of Integrated *Striga* management options in sorghum for Teso and Lango farming systems" was funded to run from September 2001 until December 2004. Seed of promising sorghum lines, provided by ARI Ilonga, has been included in on-farm trials in Uganda.

Dissemination and validation of findings CPP review of crop protection issues in semi-arid areas

The major dissemination activity was the organisation of two workshops in Tanzania in March 2003. These were held at Ukiriguru and in Dodoma attracting 57 and 47 participants respectively including district extension staff, NGOs involved in seed distribution, staff from Zonal Research programmes, ZRELOs offices, the division of Research and Development in Dar es Salaam and the media. Fifteen districts and four NGOs were represented at the Lake Zone workshop. Seven districts and two NGOs participated in the Central Zone workshop. Each workshop ran for two days. Day one was devoted to presentations of key findings from project R7564 including conclusions and recommendations from on-farm, on-station and laboratory based research. The papers covered the on-farm performance and farmer evaluation of sorghum varieties Hakika and Wahi, and recommendations on crop and soil management in relation to *Striga* control. Opportunities for use and promotion of varieties and associated management information were explored in stakeholder groups. A range of learning tools evaluated by the project to inform stakeholders of *Striga* biology and control were also presented and discussed. Presentations and discussions on the second day focused on validation of the findings of the CPP Semi-arid-review and explored the way forward for the promotion of crop protection research outputs.

The workshop papers, summaries of group discussions and recommendations of the way forward for promotion work in Central and Lake zones have been compiled in a proceedings (Lamboll *et al*. 2003 – see Annex 1). This has been circulated to CPP management and workshop participants. There was extensive coverage of the workshops in the media including television and radio interviews with project staff and articles in both Kiswahili and English medium national newspapers (see Annex 5).

In addition to the fact sheet describing sorghum cultivars Hakika and Wahi, the project contributed information for an extension leaflet on *Striga* control in Dodoma and Singida districts, prepared by Central zone Information Office (see Annex 4). Displays of Hakika and Wahi and of information on *Striga* were mounted at the National Agricultural Show in Morogoro in 2001 and 2002. Dr Mbwaga also contributed to a radio programme *Striga* management for Radio Central Zone, in Dodoma. Regional and international dissemination of project results was achieved by conference presentations and journal publications (see Annex 2).

CONTRIBUTION OF OUTPUTS TO DEVELOPMENTAL IMPACT

After four decades of independence Tanzania remains one of the 10 poorest countries in the world. Tanzania's per capita gross national product of US$265 is low and far less than Sub-Saharan Africa and East Asia's averages of US$500 and US$970, respectively (World Bank, 2000). Poverty remains widespread, deep and concentrated in the rural areas, where approximately 70 % of Tanzanians live. Agriculture accounts for 45% of national production and provides 80% of total employment and hence the sector will, for the foreseeable future, remain the backbone of the economy. The World Bank concludes that only a prospering agriculture sector can provide the basis for sustainable poverty reduction and accelerated growth in other sectors. The contribution that the outputs of research on *Striga* can make to the rural development process and poverty reduction need to be seen against this macro-economic background and the institutional changes in agricultural support agencies that are being made by the Government of Tanzania (GOT). Many studies of the slow intensification of agriculture in Tanzania identify reasons that are common in many parts of Africa – constrained access to inputs, credit and timely advice based upon sound research (World Bank, 2000). Problems of research and development in Tanzania have related to poor transfer of knowledge from research to application. Institutional change to address this has involved the decentralisation of management of extension services to local government and of research to a network on zonal programmes. Furthermore "client orientation in research and extension" is now adopted as national policy as central to the GOT Agricultural Sector Development Strategy.

By building on previous research in Tanzania and the outputs of R6654 this project has made considerable progress to:

- Make available new cultivars of sorghum that are productive in low-input systems. These have been assessed by farmers as having a niche in the cropping system of both Central and the Lake zones, are drought tolerant, palatable and potentially marketable;
- Develop a decision support tool for use by extension or NGOs to inform farmers with different soils and differential access to manure on the most appropriate cultivars to plant where *Striga* is a problem;
- Increase understanding of the need to educate farmers on the biology of *Striga* as part of the process of promoting new technology and has evaluated some learning tools which are of use in this process;
- Identify maize lines that are likely to be productive under low-input conditions in the lowlands;
- Develop a system for improving soil fertility and productivity of *Striga* infested upland rice land without recourse to expensive external, off-farm inputs.

Striga species have a widespread distribution in Tanzania and have been identified by a number of studies to be associated with, and indicative of, declining soil fertility as a consequence of continuous cultivation. The technologies developed and assessed by this project have the potential therefore for adoption over large areas of the country, provided they are adequately packaged and promoted in future NGO or district extension programmes. These technologies largely lack the need for repeated, seasonal external inputs but they are knowledge intensive. Studies have been undertaken by the project in partnership with government institutions, SUA and NGOs that have progressively adopted a client-oriented approach. Work has been completed in rural communities on-farm with the associated constraints of unreliable weather and unpredictable pest and disease attack. The varieties and practices identified for future promotion are therefore likely to be robust and offer resource poor farmers the opportunity to increase yield and farm productivity.

The challenge is now to ensure these technologies have development impact through widespread adoption, an issue addressed in the following section of this report. Tanzania has embarked on the next phase of institutional change in agriculture. This is through the preparation of a medium term plan for the Division of Research and Development in the Ministry of Agriculture and Food Security and, further decentralisation of research and extension to ensure they are responsive to needs at district level. Changes are to be implemented by late 2004. This project has encouraged collaboration of institutions at district and zonal level. This experience and the low-input technologies validated by farmers will be valuable to a number of institutions in Central and Lake Zones as they continue to evolve and plan to scale up promotion of practices which have a real chance of helping the poor.

HOW THE OUTPUTS WILL BE MADE AVAILABLE TO INTENDED USERS?

A reduction in the impact of *Striga* on cereal crops can be achieved by changing crop variety and or by modifying agricultural practices. The work undertaken over six years by R6654 and R7564 has resulted in the release of two sorghum cultivars and information about how to optimise their productivity, the identification of tolerant maize lines and, and an approach for the management of upland rice on *Striga* infested soils. Project outputs therefore comprise both "seed based" and "knowledge based" technologies, although in reality the new sorghum cultivars should not be promoted of in isolation to supporting knowledge on *Striga* biology and improved agronomic practices.

The challenge is now to ensure availability of new cultivars and to provide for maximum exposure of farmers to the available management options through trusted channels of communication. As the project ended seed of sorghum cultivars Hakika and Wahi was under multiplication as described earlier. District extension and NGO managers from semi-arid districts of Central and Lake Zone where sorghum is produced were made aware of the imminent availability of seed by presentations at the end of project workshops. The opportunity was also taken for a structured discussion about how to scale-up local seed production, through district and NGO partnerships, and how this can be accomplished as a component of on-going promotional programmes. The most favoured approach is for NGOs working with farmer groups to multiply seed at a local level and to assist with business management of the process. The formation of a company to support supply of inputs, including seed, to farmers in Central Zone by DCT in Dodoma is an interesting development that has the potential to add stability and sustainability to the process. Information on the sorghum cultivars themselves and "best bet" production practices was made available to workshop participants in the form of a fact sheet in kiswahili. This is intended for briefing of intermediate users and provides basic information that can be incorporated by Zonal Information Offices (ZIO) in training materials such as posters and leaflets aimed at extension workers and farmers. This follows the model developed in Lake Zone where researchers provide information on new technologies to the ZIO which then produces leaflets. This are developed in response to information needs of the districts and are pre-tested before final printing and distribution. An example of this is the leaflet "Udhibiti wa viduha Kanda ya Kati, Dodoma and Singida" prepared by the Central Zone Information Office on the basis of information provided by the project.

The process of information flow from research to extension, feedback of information needs from farmers and indeed a strategic vision of the communication process has reached different stages of development in different area of Tanzania. The process has been formalised through a series of committees and regular meetings in Lake Zone but appears less developed in Central Zone. Discussions at the end of project workshops (Lamboll *et al*., 2003) considered how to support this process to enhance opportunities for scaling up the promotion of CPP research outputs, including on *Striga* management, while at the same time supporting broader institutional change to strengthen client-orientated research to enhance uptake. A proposal was made to CPP to develop a project, to be implemented by an NGO, the Zonal Research Extension Liaison Office, district extension and ARI researchers to scale up promotion of outputs with emphasis on local seed supply and low cost agonomic practices. It was further proposed that the project should facilitate the development of the zonal communication strategy. This concept was accepted by CPP who invited NRI to develop a promotion project based on these principles in Central Zone. A meeting in Dodoma was scheduled for the end of June to provide an opportunity for key stakeholders to agree project outputs and activities. The new project would provide an opportunity for piloting promotion of the new sorghum cultivars, decision trees for matching cultivars to soil types and best *Striga* management practices, through the methods, including demonstrations, field days or farmer field schools, used by various organisations active in the zone.

The other seed-based output of the project is the identification of *Striga* tolerant maize lines. These had only been grown in researcher managed trials by the project. Subsequently selected lines was taken to on-farm trials in Muheza district (Tanga region) by the Eastern Zone research programme. These have also been included in trials undertaken by CPP project R8215 "Increasing food security and improving livelihoods through the promotion of integrated pest and soil management in lowland maize systems". Farmers in the villages where this project is now working have identified *Striga* and declining soil fertility as key causes of low maize yields (Ellis-Jones, 2002). Wider dissemination of information about the potential of these maize lines has been achieved through journal publication (Pierce *et al*, 2003).

Preliminary results and farmer interest in the use of *Crotalaria* to enhance the productivity of upland rice on *Striga* infested land led to a proposal to CPP to support the scaling-up of promotion of legume/rice rotations. Project R8194 was initiated in August 2002 with the aim of undertaking farmer participatory demonstrations of the use of *Crotalaria/rice,* and pigeon pea/rice rotations in Kyela District and Morogoro Rural districts. Demonstrations were initiated in a total of six villages in 2003 with supporting field days and farmer exchange visits (Mbwaga *et al*. 2003).

PUBLICATIONS SUMMARISING RESULTS FROM R7564

ANNEX 1: Working Papers and workshop proceedings – See CD attached

Lamboll (Ed.) (2000) *Striga research activities in Dodoma region: Evaluation of research trials 1999/00 season.* Working paper DFID Crop Protection Project R7564, IIonga Agricultural Research Institute, Tanzania. pp 25.

Lamboll R, Hella J, Mbwaga A and Riches C. (2001) *Striga research activities in Central Zone and Lake zone of Tanzania: Evaluation of on-farm research trials 2000/01 season*. DFID Crop Protection Project R7564, Natural Resources Institute, UK and IIonga Agricultural Research Institute, Tanzania. pp 65.

Lamboll R, Hella J, Riches C, Mbwaga A. and Ley J. (2001) Integrated *management of Striga species of cereal crops in Tanzania: Preliminary study of farmer perceptions of soil resources in Central, Lake and Eastern zones DFID Crop Protection Project R7564*, Natural Resources Institute, UK and Ilonga Agricultural Research Institute, Tanzania. pp. 43.

Lamboll R, Riches C, and Mbwaga A. (2003) *Increasing cereal productivity on Striga infested land and planning for the promotion of improved crop protection in semi-arid areas*. A report based on proceedings of workshops in Lake zone and Central Zone, Tanzania, March, 2003. Dar es Salaam, Tanzania: Division of Research and Development. pp 168.

Mbwaga A.M. and Ruches C.R. (2000) *Integrated Striga control in cereals for small scale farmers in Tanzania: Project Technical Report*. DFID Crop Protection Project R7564, Ilonga Agricultural Research Institute, Tanzania.

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Riches, C.R. (2001). *Striga* management in Uganda. *Report on a visit to Serere for CPP project R7564*. Natural Resources Institute, Chatham Maritime: UK.

ANNEX 2: Conference Papers – See CD attached

Hella, J.P., Lamboll R., Mbwaga, A.M., Riches, C., Press, M., Pierce, S., Watling, J., Ley, G., Scholes, J., Mndolwa, S. and Kapinga, E. (2002) Hassles of Conceptualising Farmer's Information Collected by Participaroty Rural Appraisal: A case of Witchweeds in Dodoma and Mwanza regions. AGREST Conference Series **5:** 84-105.

Mbwaga A.M., Riches C.R., Massawe, C. and Lamboll, R.I. (2001) Evaluation of sorghum lines for *Striga* resistance and their performance on farmers fields in Tanzania. In: Proceedings 7[th] International Parasitic Weed Symposium, eds. Fer, A., Thalouarn, P. Joel, D.M., Musselman, L.J., Parker, C. and Verkleij, J.A.C. p.246. Nantes, France: University of Nantes.

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Papers in refereed Journals – see CD

Gurney, A.L., Taylor, A. Mbwaga, A., Scholes, J.D. and Press, M.C. (2002) Do maize cultivars demonstrate tolerance to the parasitic weed *Striga asiatica*? *Weed Research*, **42**: 299-306

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ANNEX 3 Post-graduate thesis – see CD

Nyankweli, E. (2002) *Assessment of learning tools in the context of different learning approaches: A case study of Striga biology and management in Dodoma*. MA Thesis, Sokoine University of Agriculture, Morogoro, Tanzania.

Extension materials

Udhibiti wa viduha Kanda ya Kati, Dodoma and Singida (Control of *Striga* in Central Zone) Radio Central Zone programme April, 2002

Demonstration pots, rhizatrons and plots of sorghum cultivars and *Striga* at National Agricultural Show, Morogoro (August 2001 & 2002)

Central Zone Information Center (2002). Mikoa ya kanda ya Kati Dodoma and Singida (Extension leaflet on *Striga* management for Dodoma aand Singida districts) Leaflet No. 6. Central Zone Communication Office, Dodoma, Tanzania. – ANNEX 4.

ANNEX 5 Newspaper articles

April 25th 2003 Researchers breed resistant sorghum. *Business Times*, Dar es Salaam.

April 25th 2003 Striga-viduha: Magugu yanayopigwa vita kwa kuharibu mazao ya nafaka. (The weeds that destroy cereal crops) *Mitanzania Ijumaa*, Dar es Salaam.

May 2nd 2003 Falling millet harvests bad for food security. *Business Times*. Dar es Salaam.

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LOG FRAME PROJECT R7564

Narrative Summary	**Objectively Verifiable Indicators**	**Means of Verification**	**Important Assumptions**
Goal			
Benefits for poor people generated by application of new knowledge of crop protection in cereal-based semi-arid cropping systems.	To be completed by Programme Manager	To be completed by Programme Manager	To be completed by Programme Manager
Purpose			
Strategies developed to reduce impact of pests, and stabilise yields in semi-arid cereal-based cropping systems for benefit of poor people.	To be completed by Programme Manager	To be completed by Programme Manager	To be completed by Programme Manager
Outputs			
1. *Striga* tolerant sorghum cultivars validated by farmers and promoted to uptake pathways.	Foundation seed of at least one cultivar distributed to selected seed multiplication sites in Central and the Lake Zone by 10/02.	Project reports; seed under multiplication by appropriate institutions and made availbale to farmers in subsequent seasons.	Output 1: Institutions are willing and able to multiply seed for distribution to farmers.
2. Predictive tool for assessing *Striga* tolerant sorghum cultivar x soil fertility interactions developed and evaluated.	Practical guidelines for use of predictive tool available for dissemination to NARS and other organisations involved in *Striga* research in E & S Africa by 10/02.	Project reports, journal and regional conference papers.	All outputs: continuity of provision of appropriate staff for conduct fieldwork in Tanzania.
3. Integrated management options for production of *Striga* tolerant sorghum cultivars validated by farmers.	Guide lines on management options provided to extension through zonal programmes by 10/02	Extension material printed and distributed; reports distributed at national workshop.	All outputs: Weather conditions allow timely implementation of trials and adequate crop growth.
4. Approaches which facilitate farmer and other stakeholder understanding of *Striga* and *Striga* management options developed and evaluated.	Protocols available to extension organisations in Tanzania by 10/02	Printed protocols available to extension; reports distributed at national workshop.	
5. S*triga* tolerant maize cultivars based on known traits identified.	Initial selection of maize lines for field testing provided to Zonal research programmes by 09/01 and confirmed by 10/02.	Project reports, conference or journal papers. Subsequent reports of zonal research programmes.	
6. *Striga* management options for upland rice developed and evaluated.	Evaluation of rice lines and cropping patterns undertaken by 10/02.	Information available for use by extension as a report; conference paper prepared.	

Activities			
1.1 Farmer evaluation/trials of promising sorghum lines in Central and Lake zones to assess farmer acceptability, field performance (*Striga*, pests and disease), productivity and usage.	Total Budget here		
1.2 Uniformity trials for two seasons at key sites in main sorghum producing areas of Tanzania to characterise at least two lines for registration.			
1.3 Multiplication of at least two promising lines to maintain breeders seed at Ilonga.			
1.4 Identification of seed uptake pathway, including multiplication institutions and sites in Central and Lake Zone.			
2.1 Control, access to and management of soils by farmers (characterised by e.g. wealth, gender, age) investigated at benchmark *Striga* infested sites in Central, Eastern and Lake Zone.			
2.2 Farmer perceptions of soil resources and management characterised.			
2.3 Identification and chemical/physical characterisation of soils at benchmark sites.			
2.4 Laboratory assessment of tolerant sorghum cultivar x soil nitrogen content (based on 2.3) interactions.			
2.5 Validation of lab findings in on-farm trials at benchmark sites.			
3.1 Participatory on-farm trials in Central and Lake Zone to evaluate rates and timing of manure used in combination with *Striga* tolerant sorghum cultivars.			
3.2 Participatory on-farm trials in Central and Lake Zone to evaluate legume inter-crops used in combination with *Striga* tolerant sorghum cultivars.			
4.1 Litrature review of previous and on-going initiatives involving “learning by doing” in the context of *Striga* and soil fertility.			

4.2 Develop learning tools for use by farmers and other stakeholders for viewing *Striga* development and effect of management practices.			
4.3 Evaluate learning tools with extension and farmers.			
5.1 Confirmation of field tolerance in maize cultivars selected from laboratory and previous field screening studies in Kenya and Tanzania.			
5.2 Identification of critical traits that determine tolerance in maize.			
5.3 Determination of nitrogen sensitivity of *Striga* tolerance in selected maize cultivars.			
5.4 Field validation of the efficacy of nitrogen sensitivity on selected cultivars, using manure and varying rates and timing of application.			
6.1. Evaluation of rice cultivars for resistance			
6.2. Evaluation of cropping patterns for suppression of *Striga*			

Appendix 1

INTEGRATED MANAGEMENT OF STRIGA SPECIES ON CEREAL CROPS IN TANZANIA: PRELIMINARY ANALYSIS OF HOUSEHOLD SURVEY OF FARMERS ACCESS TO AND MANAGEMENT OF SOIL RESOURCES IN CENTRAL AND LAKE ZONE

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1.INTRODUCTION

1.1 Background

The semi-arid areas of Eastern and Southern Africa cover approximately one-third of the land area and support one quarter of the population of the region. Because of inherent resource limitations and a risk prone climate for arable agriculture, these areas include some of the poorest sectors of the population. Many rural households in this environment are regularly under food-deficit and poverty limits their capacity for investment in crop production, or resource conservation.

1.2 The Striga problem

Striga species are noxious weeds that are widespread constraints to the production of staple cereal crops in semi-arid areas, principally attacking maize, sorghum, finger millet and upland rice. Semi-arid areas of Tanzania lie in a zone where the three most significant *Striga* species occur that infect cereals, i.e. *S. asiatica*, *S. forbesii* and *S. hermonthica*. Most of the districts in semi-arid areas of Tanzania have been surveyed and the distribution of *Striga*, found throughout these areas, is broadly known (Mbwaga 1994; Mbwaga 1996). Grain yield loss from parasitised cereal crops is difficult to estimate with any reliability due to variations in soil fertility, infestation levels and tolerance of local varieties. However, reports of 5-30% loss of potential yield are common in the literature for various parts of Africa. Other consequences of *Striga* infestation include farm abandonment, now difficult in the face of a shortage of productive arable land, or a change of cropping pattern to less favoured, albeit resistant crop species. Reichmann *et al.* (1995) reported that 75% of farmers interviewed in Shinyanga region of Tanzania considered *Striga* an increasing problem on sorghum, on which they were unable to obtain satisfactory advice from extension on effective control strategies.

1.3 The role of soil fertility

A previous DFID CPP funded project (R6921) confirmed the importance of nitrogen in maintaining sorghum and maize productivity under infested conditions and of cultivar traits and management practices which can delay parasite attachment. On-Station work in Kenya and Tanzania has demonstrated that the use of nitrogen fertilisers (ammonium nitrate and urea, respectively) are effective in lowering numbers of emerged *S. hermonthica* and improving host performance. In Tanzania urea applications of 25 and 50 kg N ha^{-1} were sufficient to lower the detrimental effects of *S. asiatica* in maize cultivars Katumani, Staha and TMV-1 with associated increases in host carbon assimilation and grain yield. Studies in Kenya show similar results with the use of ammonium nitrate at rates of 50 and 75 kg N ha^{-1} with increased grain yield and lower *S. hermonthica* emergence in improved varieties H511 and Pioneer.
However, on-farm work in Kenya showed nitrogen applications of 50 and 75 kg N ha^{-1} increasing *Striga* emergence and grain yield was not increased above yield from plots where no fertiliser was added. The nitrogen status of infected cereals was significantly (statistically) lower on-farm compared with on-station, reflecting the soil nitrogen status. This suggests that nitrogen availability plays an important role in determining the impact of *Striga*.

The project has shown that the success of nitrogen fertilisers in both reducing the density of emerged *Striga* plants and in improving grain yield has been equivocal, varying greatly both geographically (e.g. within and between countries) and between cropping seasons, and also as a function of crop species (sorghum and maize) and genotype. Thus, there is not a universal relationship between the minimum amount of nitrogen, its form and time of application, that is required to elicit economic benefits to small holder farmers. For this reason, it is essential to understand how nitrogen perturbs the interaction between *Striga* and its cereal hosts, so that it can be used more efficiently with regard to interactions between genotype and environment.

1.4 A decision support tool for assessment of Striga tolerant sorghum cultivar x soil fertility interactions

The above findings indicate a need to identify the relationship between soil nitrogen status, and nitrogen additions with particular reference to local soil conditions and specific cultivars. This project (CPP project R7564) is, therefore, examining how tolerant/resistant lines perform on a range of soils in the Lake and Central Zones. By a combination of laboratory and field work, supported by an investigation of farmers' perceptions of soil fertility issues, it is intended to provide guidance on the deployment of new cultivars in Tanzania. Resistance screening programmes in the past have largely been based upon monitoring the number of parasite stems emerging in the field but have not taken soil fertility into account. This work should lead to the development of a decision support tool for use elsewhere in Africa and could cut the time from field screening to variety release by matching cultivar traits to soil characteristics. The development of a decision support tool involves five main activities, which are explained below.

(i)Access to and management of soils by farmers investigated at benchmark Striga infested sites in Central, Eastern and Lake Zone.

Farmers access to and management of land, is an under-researched area in Tanzania. The Tanzania Soil Fertility Initiative (SFI) aims to prepare a soil fertility strategy and action plan in which a key principle will be the adoption of people centred learning approaches. This project will contribute to the aims of SFI through detailed case studies at the selected benchmark sites. A farmer typology will be developed based on relevant criteria such as wealth, gender and age. This will then be used to select people for a detailed study of their access to different land types and how different farmers manage the land/soil resources they have available to them.

(ii)Farmer perceptions of soil resources and management characterised.

Running concurrently with the above activity, farmers' perceptions of soil resources will be investigated at benchmark sites. The approach will involve the use of participatory tools and discussion with key informants and farmer focus group. This will facilitate researcher understanding of farmers' typology of soils; their characteristics and how they are managed/utilized. This information will be used to guide researchers in the development of interventions to improve soil fertility. It will also help to make the appropriate selection of locations for soil samples at benchmark sites.

(iii)Identification and chemical/physical characterisation of soils at benchmark sites.

Soil samples from benchmark sites will be subjected to routine chemical and physical analysis. Sampling and analysis will be undertaken in collaboration with SFI and soil scientists at ARI Mlingano. Both the reproducibility and accuracy of analyses will be determined through measurements of standard samples submitted to both laboratories.

(iv) Laboratory assessment of tolerant sorghum cultivar x soil nitrogen content (based on iii above) interactions.

A range of soil fertility levels will be set up for laboratory and glasshouse trials in Sheffield. These will be used for testing the response of a range of cultivars to *Striga* infection at levels of soil nitrogen representative of the range of conditions found at benchmark sites. A random factorial design will be employed using six replicates for each combination of treatments. Through the use of the rhizotrons developed at Sheffield, it will be possible to develop a prediction of the level of tolerance that each cultivar shows at particular soil nitrogen contents. We will examine the role of soil fertility on the interactions between *Striga* and sorghum/maize at three levels: (i) germination of parasite seed and stimulant production; (ii) attachment and penetration to host roots; and (iii) effects on the subsequent growth and especially yield of cereals following attachment. Data analyses from these measurements have been routinely completed under R6921, using the appropriate transformations for non-parametric and non-interval data. Special attention will be paid to the influence of nitrogen on the timing of these processes in different genotypes.

(v) Validation of laboratory findings in on-farm trials at benchmark sites
A set of cultivars which show differential response to soil nitrogen in the laboratory trials will be grown in replicated trials at benchmark sites that differ in soil nitrogen availability. If possible a randomised block design will be used. Final trial design will however depend upon the number of cultivars selected for testing. It is appreciated that homogeneous blocks may not be available for large blocks on-farm and that an incomplete block design may be more appropriate. Further discussion on the relative merits of the field plot design will be necessary prior to initiating the trials. Site identification will be based upon a working classification of soils derived from farmer perception studies, complimented by characterisations derived from laboratory soil analysis. Vegetative growth will be monitored using non-destructive methods; e.g. plant height to the ligule of the youngest expanded leaf, which has been found to be a sensitive indicator of sorghum response to infestation. Yield data will also be collected and the results used to validate the findings from the laboratory trials. These will then be referenced to the farmers perceptions of the fertility of S*triga* infested soils to match cultivars to the categories of soil identified by farmers. The essential feature of this process will be to enable the recommendations on cultivars to be matched with the farmers understanding and classification of soils. This information will be of value locally to the government extension service and NGOs for planning the deployment of resistant and tolerant cultivars. It is hoped that the process followed through the activities leading to this output will find applicability for sustained production of tolerant cereal cultivars in parasite infested land elsewhere in Africa.

This paper is primarily concerned with activity i above, ie access to and management of soils by farmers investigated at benchmark Striga infested sites in Central and Lake Zone.

2. METHOD

The villages selected for the survey have all been involved in the Integrated Striga Management project for a number of years. These were Mvumi makulu and Chipnaga A villages in Dodoma Rural district, Central Zone and Mwagala and Iteja villages in Misungwi district Lake Zone. Two exercises were carried out prior to the questionnaire survey.

A study was carried out of farmers' perceptions of soil resources in Central, Lake and Eastern zones[1] and this provided farmers' classifications of soils in their own community. In Lake Zone, the Sukuma classification is widely recognised and used by eg researchers and extensionists. In Central Zone there is no equivalent classification. In the two villages the project is focused the people speak kigogo, but according to some reports the people of Mvumi makulu consider themselves 'true Wagogo' and those from Chipanga 'A' Wanyembwa. The biophysical conditions in the two Central Zone villages are also quite different. However, the study successfully provided a soil classification for the four villages

Wealth ranking was carried out in each of the villages as an initial separate exercise. A group of informants were then asked how different people could be differentiated according to how well off they were. From this discussion criteria emerged for different groups of households. In order to facilitate comparison across sites, the key informants in each village were encouraged to group their community into four groups from 'least well off' to 'best off'. In each village, a random sample of 100 households were listed and the names written on two sets of cards. Two separate groups of informants were then asked to put each household in one of the four groups. Having completed this exercise, each name was considered and agreement sought between the two sets of key informants as to which household the group belonged. This provided an indication of the proportion of households in each category in each village. The criteria varied significantly between the villages eg the people in Chipanga 'A' are clearly much less well off in general than the other villages.

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Although there are limitations to making comparisons across the villages in this way, it does provide a means of quickly differentiating the community in order to gain an indication as to how access to and management of soils differs according to wealth.

In the questionnaire survey 30 households were selected from the list of 100 randomly selected households (see above) in proportion to the number in each wealth group (see Table 1).

Table 1 Percentages of households in each wealth group based on wealth ranking of 100 households and number of households interviewed in questionnaire survey

District	Village		Wealth groups				
		No.of households in village	1(Most well off)	2	3	4 (Least well off)	Total
Dodoma Rural	Chipanga 'A'	NA	3% 2	3% 2	10% 3	84% 23	100% 30
	Mvumi makulu	2017	<1% 1	5% 2	87% 24	8% 3	100% 30
Misungwi	Iteja	609	<1% 1	14% 4	37% 11	46% 14	100% 30
	Mwagala	410	6% 2	7% 2	29% 10	58% 16	100% 30

NA = Not available

The number of households in the better off groups tends to be very small and because only 30 households were surveyed in each village, including even one household from this category can over-represent the group. However, the intention is to provide an indication of variation as well as the overall situation in each village. A larger sample may be taken at a later date for further statistical analysis.

The unit of analysis is basically the household, according to household lists available in the villages. Where lists were not available they were put together by officials in the villages and are thought to be reasonably comprehensive. The interviewee in most cases is the head of household, but if they were not present, in some cases another member of the household provided the information. This means, for example, that in some cases the wife of the head provided the information. In the analysis any differentiation by gender takes into account who in the household provided the information.

Table 2 Breakdown of sample

		Male			Female			
		Head	Other	Total	Head	Other	Total	Overall Total
Dodoma Rural	Chipanga 'A'	23	0	23	5	2	7	30
	Mvumi makulu	13	0	13	12	5	17	30
Misungwi	Iteja	23	0	23	5	2	7	30
	Mwagala	24	0	24	6	0	6	30

3. RESULTS

Characteristics of households

Table 2 provides an indication of the variation between wealth groups and villages including some criteria which generally emerged from the wealth ranking exercise.

Cattle are a significant indicator of wealth across all four villages. The most extreme situation is in Chipanga village where there are some very large cattle owners, but in the poorest group (an estimated 84% of the community) only one respondent had cattle. In Mvumi makulu cattle have been removed from the division under the HADO because of environmental degradation and remaining cattle are meant to be zero-grazed. Although cattle are traditionally an important wealth indicator in this village, during the wealth ranking exercise there was much discussion as to whether it was still relevant. In Lake Zone cattle is a useful indicator of wealth, but the uneven distribution is not so pronounced as Central Zone. Households in both zones may gain access to the benefits of cattle (eg milk, manure) without owning through various borrowing-type arrangements with the cattle owners. Access to cattle for ploughing is a key factor in soil management in Lake Zone, whereas Central Zone there is very little use of draught animal power..

Hiring in of labour and selling of labour are also generally applicable indicators. Almost all the households in the two better off wealth groups hired in labour. At least 30% of households in the two least well off households hired out household labour and in the case of least well off group in Chipanga 74% of households hired out their labour. Availability of labour is a key factor determining farmer decision-making in relation to soils and all other aspects.

Food security is a major issue in semi-arid areas. Misungwi district (Lake Zone) generally has higher rainfall and sometimes two seasons compared to Dodoma Rural in Central zone. However, the situation varies from year to year both between and within zones, districts and even villages. Over the 12 months prior to the survey, Mvumi makulu appears to have experienced more food secure months than the other three villages (average of 10 months), compared to only six months in Chipanga. Generally, the better off households are more food secure. However, this appears to not always having been the situation over the last months. In good years (essentially related to rainfall) households in all wealth groups appear to achieve actual or close to food security. In Lake Zone many farmers reported a surplus equivalent to many months food. In bad years all wealth groups in almost all villages appear to have insufficient food. Chipanga again appears to have the worst problems.

Non-farm income appears to be important across most wealth groups in the four villages. In the two Central zone villages non-farm earnings appear to represent a higher proportion of income for the less well of groups, whereas in Lake Zone there was no clear pattern. The actual source of income varies between the groups with the poorer groups engaged in activities such as labouring (*Vibarua*), making local brew, making pottery, charcoal making. Whereas the better off groups were involved in large scale trading (in some cases owning shops). Remittances were frequently reported by the poorer groups, but also by some households in the better off groups.

Access to land was reported as an indicator wealth and, in general, better off households have access to more land than less well off households. Interestingly, in three of the four villages households in the second wealthiest group appear to have access to most land. Perhaps surprisingly households in Central Zone had on average access to less land than those in Lake Zone. So the less well off groups in Mvumi makulu and Chipanga are the household with access to least land, 0.9 acres and 3.3 acres per household respectively.

Table 3 Characteristics of households by village and wealth group

DISTRICT	VILLAGE	Wealth rank	Sample	No. female head	Mean age*	% hhold with cattle	Cattle/ hhold	% hiring in labour	% hiring out labour	Mean no. of months with enough food in last 12 months	Mean no. of months with enough food in a GOOD year	Mean no. of months with enough food in a BAD year	% with non-farm income	Land/ hhold (acres)	Shambas/ hhold
Dodoma R	Chipanga A	1	2	0	41	100	104	100	0	10	12	5	50	14.5	3
		2	2	0	60	50	50	100	0	12	12	4	100	13.5	3.5
		3	3	0	42	33	1.7	67	33	5	12	4	100	3.5	4
		4	23	5	53	4	.0.4	4	74	5	11	2	96	3.3	2.3
		All	30	5	52	17	10.7	23	60	6	11	3	93	4.7	2.6
	M.Makulu	1	1	0	66	100	10	100	0	12	12	12	0	10	6
		2	2	2	56	100	3	100	0	8	12	6	0	15	5.5
		3	24	9	47	5	0.1	17	54	10	12	5	87	4.3	3.1
		4	3	1	74	0	0	33	33	10	12	6	100	0.9	1
		All	30	12	53	13	0.6	27	47	10	12	5	80	4.9	3.1
Misungwi	Iteja	1	1	1	70	100	50	100	0	8	12	3	100	7	4
		2	4	0	41	100	11	100	25	10	12	4	100	16	4.75
		3	11	1	48	45	5	55	64	7	12	4	91	8.6	2.7
		4	14	3	47	14	5	4	43	10	12	4	93	4.9	2.9
		All	30	5	47	40	5	57	47	8	12	4	93	7.7	3.1
	Mwagala	1	2	0	75	100	13	100	0	12	12	6	50	11	4.5
		2	2	0	70	100	31	50	50	12	12	6	50	18	5.5
		3	10	4	60	60	5	60	30	10	12	4	70	6.8	3.7
		4	16	2	39	31	1.1	44	38	8	11	5	88	5.5	3.4
		All	30	6	50	50	5	53	33	9	12	5	77	7.1	3.7

- Age of heads of households only included

Table 4 Characteristics of households by village and gender of head of household

DISTRICT	VILLAGE	Head of household	Sample	Mean age*	% hhold with cattle	Cattle/ hhold	% hiring in labour	% hiring out labour	Mean no. of months with enough food in last 12 months	Mean no. of months with enough food in a GOOD year	Mean no. of months with enough food in a BAD year	% with non-farm income	Land/ hhold (acres)	Shambas/ hhold
Dodoma R	Chipanga A	Female	5	66	0	0	20	40	4	11	2	100	1.5	1.6
		Male	25	48	20	13	24	64	6	11	3	92	5.4	2.8
		All	30	52	17	11	23	60	6	11	3	93	4.7	2.6
	M.Makulu	Female	12	48	17	0.5	27	50	10	12	5	83	5.0	3.1
		Male	18		11	0.7	28	44	10	12	5	78	4.7	3.1
		All	30	53	13	0.6	27	47	10	12	5	80	4.9	3.1
Misungwi	Iteja	Female	5	64	20	10	20	40	6	11	3	100	5.0	2.8
		Male	25	43	44	4	64	48	9	12	4	92	8.3	3.2
		All	30	47	40	5	57	47	8	12	4	93	7.7	3.1
	Mwagala	Female	6	58	33	4	50	50	9	12	4	100	3.3	2.5
		Male	24	49	54	5	54	29	9	12	5	71	8.1	4.0
		All	30	50	50	5	53	33	9	12	5	77	7.1	3.7

- Age of heads of households only included

Summary Tables

Table 5 Farmers' perceptions of Striga by wealth group (% of shambas infected in each wealth group)

	Dodoma						**Misungwi**						**Dodoma and Misungwi**				
	1	2	3	4	All		1	2	3	4	All		1	2	3	4	All
Zero	75	50	38	55	48		43	50	32	46	42		58	50	36	50	45
Low	25	22	41	23	32		36	11	33	31	29		31	15	38	28	31
High	0	28	21	21	20		21	39	35	23	29		12	35	27	22	25
Number of shambas	12	18	86	56	172		14	28	63	97	202		26	46	149	153	374

Table 6 Farmers' Perceptions of Striga by village (% of shambas infected in each village)

	Chipanga	**Mvumi makulu**	**All**		**Iteja**	**Mwagala**	**All**
Zero	60	37	48		36	47	42
Low	24	38	32		31	28	29
High	15*	25	20		33	25	29
Number of shambas	78	94	172		94	108	202

*Doesn't equal 100% due to rounding

Table 7 Farmers' Perceptions of Striga by gender of respondent (% of shambas infected in each village)

	Dodoma				**Misungwi**				**Dodoma and Misungwi**		
	Female	Male	All		Female	Male	All		Female	Male	All
Zero	31	57	48		35	44	42		33	49	45
Low	42	26	32		27	30	29		37	28	31
High	27	17	20		38	27	29		31	23	25
Number of shambas	64	108	172		34	168	202		98	276	374

Table 8 Access to different soil types by village and wealth group

DISTRICT	VILLAGE	Soil type	WEALTH GROUP				Total
			1	2	3	4	
Dodoma	**Chipanga**	Ilolo		2	3		5
				28.6%	25.0%		6.4%
		Isangha	1		1	9	11
			16.7%		8.3%	17.0%	14.1%
		Ngogomba	1	4	5	30	40
			16.7%	57.1%	41.7%	56.6%	51.3%
		Nguluhi	1		3	5	9
			16.7%		25.0%	9.4%	11.5%
		Nyika	2			3	5
			33.3%			5.7%	6.4%
		Other	1	1		6	8
			16.7%	14.3%		11.3%	10.3%
			6	7	12	53	78
			100.0%	100.0%	100.0%	100.0%	100.0%
	M.Makulu	Chitope		3	9		12
				27.3%	12.2%		12.8%
		Ilolo			1		1
					1.4%		1.1%
		Isangha	2	6	30	1	39
			33.3%	54.5%	40.5%	33.3%	41.5%
		Isangha chitope	3		11	1	15
			50.0%		14.9%	33.3%	16.0%
		Nguluhi		1	17	1	19
				9.1%	23.0%	33.3%	20.2%
		Other	1	1	6		8
			16.7%	9.1%	8.1%		8.5%
			6	11	74	3	94
			100.0%	100.0%	100.0%	100.0%	100.0%
Misungwi	**Iteja**	Ibushi		6	7	9	22
				31.6%	23.3%	22.0%	23.4%
		Itogolo		2	6	6	14
				10.5%	20.0%	14.6%	14.9%
		Luseni	1	6	8	14	29
			25.0%	31.6%	26.7%	34.1%	30.9%
		Mbuga	2	4	7	6	19
			50.0%	21.1%	23.3%	14.6%	20.2%
		Other		1	2	3	6
				5.3%	6.7%	7.3%	6.4%
		Shilugu	1			3	4
			25.0%			7.3%	4.3%
			4	19	30	41	94
			100.0%	100.0%	100.0%	100.0%	100.0%
	Mwagala	Ibushi	1			2	3
			10.0%			3.6%	2.8%
		Itogolo			1	6	7
					3.0%	10.7%	6.5%
		Luseni	6	5	22	28	61
			60.0%	55.6%	66.7%	50.0%	56.5%
		Mbuga		3	3	5	11
				33.3%	9.1%	8.9%	10.2%
		Other	3	1	6	12	22

			30.0%	11.1%	18.2%	21.4%	20.4%
		Shilugu			1	3	4
					3.0%	5.4%	3.7%
			10	9	33	56	108
			100.0%	100.0%	100.0%	100.0%	100.0%

Table 9 Land acquisition by wealth group

			WEALTH GROUP				**Total**
DISTRICT	**VILLAGE**		1	2	3	4	
Dodoma	**Chipanga**	Gift				10	10
						18.9%	12.8%
		Inherited		3	1	13	17
				42.9%	8.3%	24.5%	21.8%
		Other	5	2	2	26	35
			83.3%	28.6%	16.7%	49.1%	44.9%
		Purchased	1	2	7		10
			16.7%	28.6%	58.3%		12.8%
		Village govt			2	4	6
					16.7%	7.5%	7.7%
			6	7	12	53	78
			100.0%	100.0%	100.0%	100.0%	100.0%
	M.Makulu	Borrowed			1		1
					1.4%		1.1%
		Gift			10		10
					13.5%		10.6%
		Inherited	6	3	37	3	49
			100.0%	27.3%	50.0%	100.0%	52.1%
		Other		4	8		12
				36.4%	10.8%		12.8%
		Purchased		3	5		8
				27.3%	6.8%		8.5%
		Village govt		1	13		14
				9.1%	17.6%		14.9%
			6	11	74	3	94
			100.0%	100.0%	100.0%	100.0%	100.0%
Misungwi	**Iteja**	Gift		1	2	1	4
				5.3%	6.7%	2.4%	4.3%
		Inherited		15	19	32	66
				78.9%	63.3%	78.0%	70.2%
		Purchased	3		5	3	11
			75.0%		16.7%	7.3%	11.7%
		Village govt	1	3	4	5	13
			25.0%	15.8%	13.3%	12.2%	13.8%
			4	19	30	41	94
			100.0%	100.0%	100.0%	100.0%	100.0%
	Mwagala	Borrowed				2	2
						3.6%	1.9%
		Gift			1	5	6
					3.0%	8.9%	5.6%
		Inherited	1	2	18	35	56
			10.0%	22.2%	54.5%	62.5%	51.9%
		Purchased	8	6	6	9	29
			80.0%	66.7%	18.2%	16.1%	26.9%
		Rented			1	2	3

			3.0%	3.6%	2.8%
Village govt	1	1	7	3	12
	10.0%	11.1%	21.2%	5.4%	11.1%
	10	9	33	56	108
	100.0%	100.0%	100.0%	100.0%	100.0%

Table 10 Last time animal manure was applied to a shamba by village and wealth group

			WEALTH				Total
DISTRICT	**VILLAGE**		1	2	3	4	
Dodoma	**Chipanga**	1975			1	1	2
		1988				1	1
		1989				1	1
		1992			1		1
		1993		1			1
		1996			2		2
		1998				3	3
		1999		2	1	6	9
		2000	2	1	2	15	20
		Never	4	3	5	26	38
		Total	6	7	12	53	78
	M.Makulu	0			1		1
		1971			2		2
		1972			1		1
		1974			4		4
		1982			1		1
		1984		1			1
		1985				1	1
		1986			1		1
		1994		1	1		2
		1999			2		2
		2000		1	1		2
		Never	5	8	60	2	75
		NR	1				1
		Total	6	11	74	3	94
Misungwi	**Iteja**	1978				1	1
		1980				1	1
		1986			1		1
		1990				1	1
		1995			1		1
		1996			1		1
		1997			1		1
		1998	1	1			2
		1999		1	2	1	4
		2000		2	4	7	13
		Never	3	15	20	30	68
		Total	4	19	30	41	94
	Mwagala	1990	1		1	3	5
		1993		1			1
		1995				1	1
		1997			1		1
		1998	1			1	2
		1999	1	2	4	2	9
		2000		1	9	11	21
		2001	1				1
		Never	6	5	18	38	67
		Total	10	9	33	56	108

Table 11 Last time chemical fertilizer was applied to a shamba by village and wealth group

				WEALTH GROUP				Total
DISTRICT	**VILLAGE**			1	2	3	4	
Dodoma	**Chipanga**	P1CH	Never	6	7	12	53	78
		Total		6	7	12	53	78
	M.Makulu	P1CH	1974			2		2
			1986			1		1
			1993		1			1
			1994		1			1
			Never	6	9	71	3	89
		Total		6	11	74	3	94
Misungwi	**Iteja**	P1CH	Never	4	19	30	41	94
		Total		4	19	30	41	94
	Mwagala	P1CH	1972			1		1
			1993		1			1
			1999	1				1
			2000			1	5	6
			2001				1	1
			Never	9	8	31	50	98
		Total		10	9	33	56	108