Aspects of Applied Biology 75, 2005
Pathways out of Poverty

Lessons learned in developing IPM options to improve maize forage yield and quality for small-scale dairy farmers in central Kenya

A J MURDOCH[1], J M NJUGUNA[2], P T DORWARD[1], D ROMNEY[3], B A LUKUYU[2], D M MWANGI[2] and E OWEN[1]

[1]*School of Agriculture, Policy and Development, The University of Reading,PO Box 237, Earley Gate, Reading RG6 6AR, UK*
[2]*Kenya Agricultural Research Institute, National Agricultural Research Centre, Muguga, PO Box 30148, Nairobi, Kenya*
[3]*International Livestock Research Institute, PO Box 30709, Nairobi, Kenya*

Summary

Many small-scale farmers in central Kenya stall-feed cattle. A rapid rural appraisal (RRA) in the Kiambu district showed that 25% of the forage came from the maize crop. Crop protection advice to farmers generally focuses on maize for grain and ignores the importance of the dairy animal in the livelihoods of these resource-poor livestock keepers. The RRA showed that the three principal biotic constraints on the maize crop were *maize streak virus* disease (MSVD), maize stalk borer and weeds. Experiments showed that early MSVD infections reduced forage offtake from the maize and had some effect on crop quality for livestock production. Cultivars tolerant to MSVD such as KH521 and PAN67 alleviate yield losses, and their taste and cooking quality is acceptable to the farmers. However, breeders do not appear to allow for the dual purposes of the crop and neutral detergent fibre concentrations were higher and crude protein concentrations lower in KH521.

The need to evaluate all new technologies using farmer participatory methods is emphasised especially where complex changes to crop planting arrangements are envisaged.

Key words: Maize, dairy, forage, maize streak virus disease, multi-disciplinary project, policy implications, livelihoods

Introduction

The Department For International Development (DFID) project “Strategies for feeding smallholder dairy cattle in intensive maize forage production systems and implications for integrated pest management” (R7955) commenced in April 2001 with a final budget of c. £310,000 after including three add-ons/extensions to the original project. It is a multi-disciplinary collaborative research project with a research team consisting of forage and livestock specialists, crop protectionists and socio-economists from both Kenya and the UK. Dissemination of outputs involved a variety of governmental and non-governmental organisations. A major challenge of the project was co-ordinating the interests, objectives and activities of livestock and crop specialists. This co-operation was needed at all levels of the project from the sponsors – the project was jointly funded by the Livestock Production and Crop Protection Programmes of DFID – through the actual researchers to the extension personnel. At every level, people naturally tend to focus on their own specialist disciplines leaving the end-users of the technologies – the farmers – to integrate information from different sources. This multi-disciplinary project sought to bring together specialists from different disciplines so that the focus was on integrating the technologies into the farming and cropping systems actually practised.

The project therefore throws light on the nature of such projects and several lessons are there to be learned; the purpose of this paper is to highlight some of these lessons. A simple example emphasises this point: it is very easy for the crop protection specialist to forget that an important staple cereal crop such as maize is also an important source of forage, and even in years when the grain loss is zero, some forage will still be produced. Ensuring crop specialists remembered to measure forage, and livestock and forage specialists to think how the complex semio-chemical interactions of the push-pull habitat management system affected the sequence of harvesting Napier grass, and encouraging researchers to conduct farmer participatory research, were important lessons underlying any successful outcomes of this project. These were lessons for the project team. This paper concerns wider implications.

The key beneficiaries were resource-poor small-scale maize/dairy livestock producers and non-livestock keepers supplying maize forage to the same in intensive/peri-urban crop/livestock systems in central and other regions of Kenya where overcrowding and/or poverty are problems. The study was sensitive to the gender of farmers as many maize/dairy households are female-headed. Landless livestock farmers were relatively rare in the study area.

The ultimate goal of the project was to improve the livelihoods of smallholders growing maize and producing milk by developing and promoting integrated pest, weed and disease management strategies of maize that increase the seasonal availability of forage from maize and weeds and hence greater milk production.

Maize/dairying in Central Kenya

Maize is the staple food for 24 million households in East and southern Africa. Research into agronomic practices to optimise grain yields is a priority for the Kenya Government because of the critical role played by maize in food security. As a result, agronomic evaluation and crop husbandry recommendations for maize focus on maximising grain yield but ignore the maize crop as a source of forage for livestock production: despite the value of the crop residue being between one third to half the value of the grain produced (McIntire *et al.*, 1992).

In the central Kenya Highlands, economic activity is dominated by smallholder intensive agriculture and industries based on cash crops such as tea and coffee. Dairying is the most important agricultural activity after tea and coffee growing (Staal *et al.*, 1997). Dairy animals are fed in zero-grazed or semi-zero-grazed systems, mainly on "cut and carry" forage maize residues, weeds and crops such as Napier grass (*Pennisetum purpureum*) (Farrell, 1998). For example, in the Kiambu District with a population of 744,010, 48% of 189,709 households zero-graze dairy cattle, so that dairy livestock ownership helps alleviate poverty for many. Farming in this area is becoming more intensive, with pressure on the land rising as population size increases: reports on average farm sizes range from 1.1 to 2.0 ha per household (Gitau *et al.*, 1994; Staal *et al.*, 1997). In the long-term, this intensification is expected to lead to a decline in the availability of purpose-grown forage such as Napier. In the short-term, the area under Napier may still be increasing. Therefore, producing sufficient forage for dairy cattle is expected to become increasingly difficult for farmers. For example, one survey in the central Kenya Highlands highlighted low dry matter intake as one of the most important constraints to dairy production (Omore *et al.*, 1996). Of the land available to dairy farmers, 27-50% of the area is occupied with forage/maize. The project's rapid rural appraisal showed that while Napier grass was undoubtedly the main forage source (40%), the maize crop contributed 24% and weeds from the maize crop, a further 5% of annual forage supplies (Fig. 1).

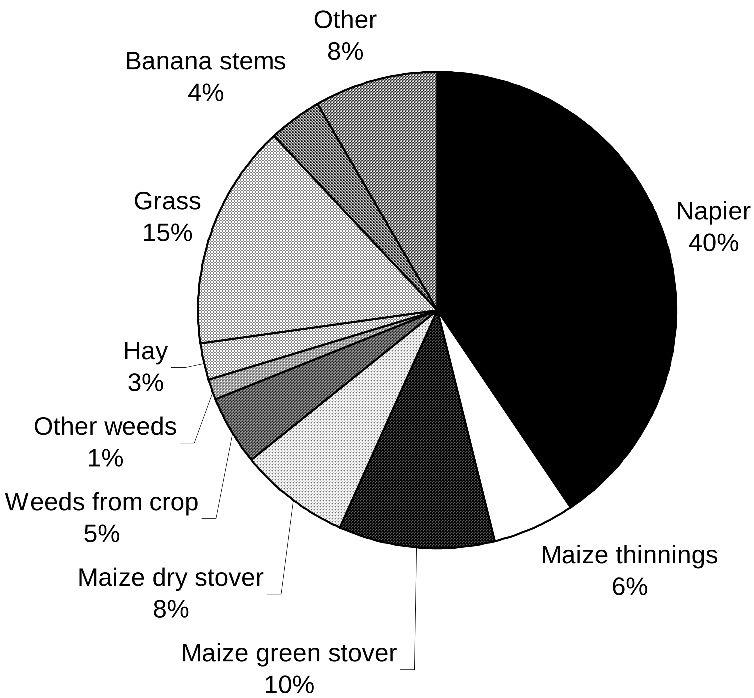

Fig. 1. Total annual usage score for different forages in Kiambu, Kenya.
(From Murdoch *et al.*, 2003)

However, forage (in the form of maize thinnings and leaf strippings, weeds and forage crops such as Napier grass) is abundant only during the rainy seasons. Just over 50% of farmers indicated that Napier grass was unavailable during the dry months. Therefore, farmers are forced to utilise whatever forage materials are available during this period. One survey showed that dry maize stover accounted for nearly 65% of dry matter intake of dairy cattle during the October dry period (KARI/MoA/ILRI Smallholder Dairy Project). Methu *et al.* (1997) have shown that there is a positive correlation between stover intake and milk yield. Therefore, practices which increase the health and yield of maize, thereby improving the amount of forage available, will, in turn, increase milk production. Seasonal availability of forage will to some extent be relieved if stover production is greater, but maize stover is a fairly low quality forage. This project has therefore not only sought to increase forage production but also to promote small-scale silage-making technologies to conserve higher quality forages produced during the rainy seasons for use during the dry season. The project would therefore not only enhance production but also the seasonal availability of forage.

Even though maize is so important to food security in Africa, research has generally ignored the use of crop residues, thinnings, leaf strippings and some weeds as forage. The project therefore aimed to investigate the impact of maize streak virus disease and weeds on forage yield and quality. Results confirmed that *maize streak virus* disease (MSVD) not only reduced yields of forage from maize, but that resistant cultivars could mitigate that loss (Fig. 2).

The interaction with livestock is also crucial for maize-dairy farming. Forage requirements result in farmers sowing densely with several seeds per planting hill and thin for forage as late as tasselling. These practices may also affect disease spread in the crop and dense planting may suppress weeds. Feeding diseased plants and weeds to animals raises the question of spore and seed dissemination with manure. The potential for spread of maize head smut and weed seeds in manure was also studied.

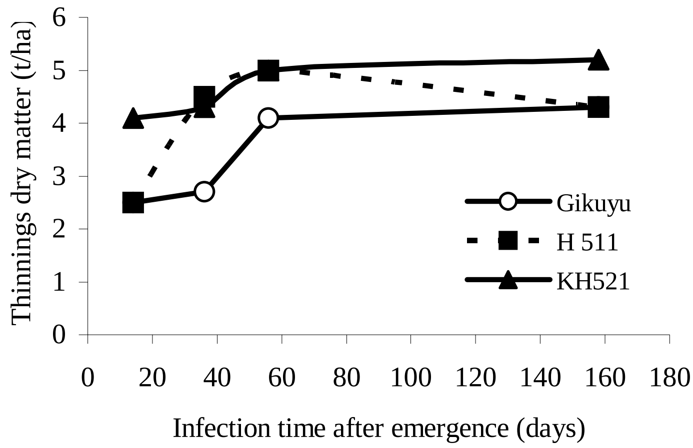

Fig. 2 Yields (dry matter in t/ha) as a function of the period after crop emergence (12 November 2001) of artificial inoculation with *maize streak virus* of maize thinnings in 2001 short rains at KARI-NARC-Muguga, Kiambu, Central Kenya. The experiment included MSVD resistant (KH521) and susceptible cultivars (H511) and a local landrace, Gikuyu. All plants were artificially infected with infective leafhoppers, except for the uninfected control, which is plotted as though it were infected on the final grain harvest date – 158 days after emergence. Plots were thinned for forage from two to one plant per planting hole at 90% tasselling, which is consistent with local farmer practice – Gikuyu on 28 January 2002 (77 days post-emergence – dpe), H511 on 11 February 2002 (89 dpe) and KH 521 on 26 February 2002 (106 dpe). The LSD value ($P<0.05$) is 0.5 t/ha. (Adapted from Murdoch *et al.* 2003.)

Implications for plant breeders and agronomists

Plant breeders and maize agronomists have tended to ignore the fact that maize is a dual purpose crop for many farmers in the East African Highlands. Several examples can be given. Disease resistant cultivars are sometimes bred with highly lignified cell walls as a defence mechanism against disease (Ride 1983). Hans *et al.* (2001) also reported that selection for disease resistance may alter neutral detergent fibre concentrations (NDF) of forage. NDF reflects the extent of lignification, and lignin fibres are usually less easily digested by rumen bacteria (Han *et al.* 2001), so that lower NDF values may indicate a better quality forage. Insect pest and disease resistance is sometimes achieved by increasing the fibre content and toughness of leaves, with concomitant reductions in digestibility and forage quality. The MSVD resistant cultivar promoted by R7955, KH521, was characterised by higher NDF concentration (Table 1) compared to the commonly grown susceptible hybrid, H511 and a landrace, Gikuyu, selected by farmers in the Central Kenyan Highlands. There was some evidence of a similar trend for higher NDF concentration in the resistant PAN 67 compared to H511 in the next season (the 2002 short rains). Crude protein concentrations (CP) were also lower in forage from the resistant cultivar (Table 1). Although the lower protein concentration of KH521 was generally compensated by a higher dry matter yield (data not shown), the uses to which a crop is put and their economic values should be taken into account in crop protection strategies.

Chemical composition, in terms of CP and NDF in leaves and stems, indicates nutritional quality although the most accurate method is through *in vivo* forage feeding experiments. Such experiments require large quantities of forage and many similar animals. Where many forage samples, originating from small plot experiments, have to be evaluated at different times and in different seasons, as in this project, *in vivo* experimentation is impractical; digestibility and *in* *vitro* methods can, however, be employed to estimate *in vivo* performance. Using this method, many differences could be highlighted. Here it is important to mention that despite the lower NDF and higher CP values of the susceptible cultivars, the total digestible dry matter yield of the resistant KH521 equalled that of uninfected or late infected thinnings of the other two cultivars, and exceeded the others for crops infected with MSVD 14 days post-emergence (Fig. 3).

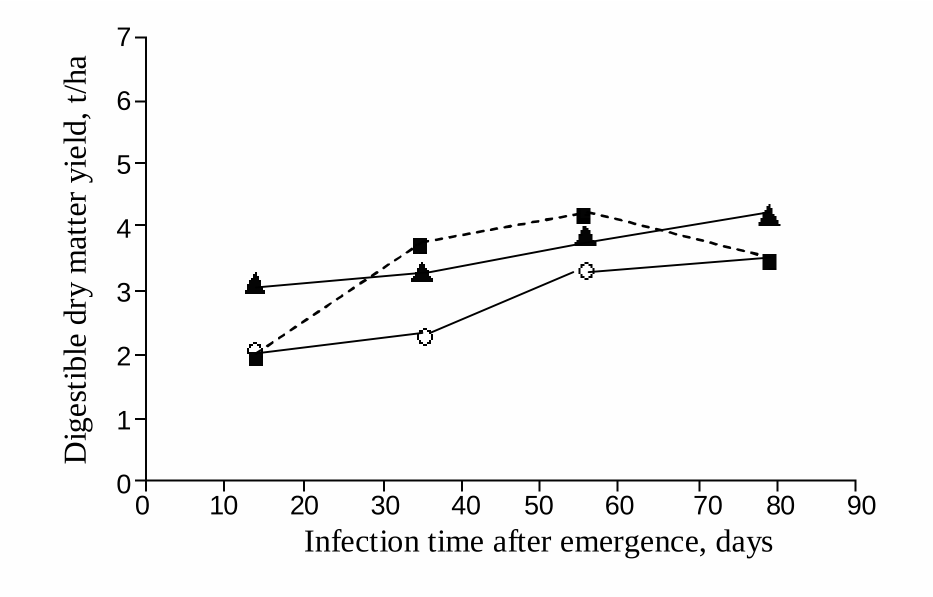

Figure 3. Yields of digestible dry matter of maize cultivars, Gikuyu (○), H 511 (■) and KH 521 (▲) as a function of the date of artificial inoculation with *maize streak virus* of maize thinnings in 2001 short rains. Digestible dry matter (Mauricio *et al.*, 1999) was determined after digestion of small sub-samples of forage using rumen fluid obtained before the morning feeding (06.30) of three stall-fed fistulated steers. The steers weighed about 400 kg and were being fed on fresh *Pennisetum purpureum* Schumach. (Napier grass) *ad libitum* with no concentrate supplements. See Figure 2 for MSVD treatment details.

Table 1. *Neutral detergent fibre (NDF) and crude protein (CP) concentrations of forage from three maize cultivars in the short rains season 2001 at Muguga in Kiambu District, Central Kenyan Highlands. Values are means for plots either uninfected or infected with MSVD 14, 35, 56 days post crop emergence except for CP stover values, which are for uninfected plots only*

Maize cultivar	NDF of thinnings g/kg DM	NDF of stover g/kg DM	CP of thinnings g/kg DM	CP of stover g/kg DM
Gikuyu	472	675	113.5	56
H511	476	684	100.8	36
KH 521	542	703	74.8	41
LSD (P=0.05)	10.5	9.8	9.6	11

Local cropping systems and crop management practices must also be considered by the breeders and advisors, yet clear evidence arose in this project of the failure to do so. Reduced farm sizes have forced farmers to maximise food and feed by growing maize in place of planted forage (Staal *et al.* 1998). Intensification of farms has led to farmers adopting practices as dense planting of maize, which is then thinned progressively to provide forage, relay cropping, delaying the second (hand)weeding of maize so that larger weed plants can be fed to animals, and harvesting green maize for sale (Lukuyu, 2005). These practices are ignored to the extent that one of the MSVD resistant cultivars being promoted in the region, PAN67, is marketed with leaflets explicitly advising farmers not to plant densely.

Economic evaluations

In assessing the advantage of new varieties and crop technologies, economic evaluation is clearly essential. This must take account of all inputs and outputs. Higher seed rates for dense planting and outputs of thinnings, stover, intercrop and edible weeds need to be accounted for in addition to grain, whereas only maize grain and cob yields have been considered in much crop research. Long-term implications of weed control to the following season should also be taken into account; it has been shown that plots left unweeded for any reason take longer to weed by hand in the following season. The extra forage produced through improved IPM was, however, largely produced during the wet seasons when forage is more generally available and its price low. The project therefore promoted small-scale conservation techniques which greatly enhanced the benefits of the IPM technologies thereby contributing to alleviation of seasonal forage shortages and substantially increasing the value of the crop (Murdoch *et al.*, 2004). Interestingly, the push-pull habitat management system for maize stem borer control had negative returns in the first season due to the cost of setting up the plots, but its profitability was considerable once forage conservation was taken into account.

Participatory methods

Introducing the push-pull system offers advantages of reducing stem borer damage to maize and providing additional forage from the *Desmodium*, which is grown between maize rows, and Napier, two or three rows of which surround the maize plot. However there are disadvantages and management changes for farmers that need to be considered carefully, such as extra activities and inputs (especially labour) associated with planting and harvesting Napier and *Desmodium*. Some interrows normally used for food are lost since the *Desmodium* is planted instead of other intercrops such as beans and the Napier perimeter reduces the area of maize in a plot of land. Participatory budgets (Galpin *et al.*, 1999) were used to explore these changes with farmers. Because the push-pull system lasts for several years – *Desmodium* and Napier are perennial – there are implications for the amounts and spacing of crops over several seasons. To explore the changes required, the farmers in small groups conducted a plot mapping exercise in which a farmer in each group drew a simple map of a plot on their farm and then drew on the *Desmodium*, Napier and other crops in the first four seasons (one map for each season). This enabled farmers to discuss and see the implications of different spacings and combinations and to see how other crops which are sometimes grown instead of maize would be located between the fixed rows of *Desmodium*. A detailed protocol for this procedure, which is essential for dissemination and adoption, is in preparation

Farmers found the exercise very useful: preparing the budgets involved much discussion about the system, e.g. agreeing when the *Desmodium* can be harvested and how much it would produce, considering how much maize would be produced in the different seasons. These all led to a much clearer understanding of the push-pull system itself. The budgets enabled farmers to see what activities were involved and what resources such as labour are needed. Similarly, the budgeting enabled farmers to explore how much extra forage may be produced by the Napier and *Desmodium* and when, in the second year. Also the effects on maize and intercrop yields were positive but not if *Desmodium* is spaced too closely. Several farmers were extremely pleased and surprised to see how much profit they made from their maize – the existing system as well as from the push-pull. Some were also proud of the budgets produced. Lastly, some farmers having completed the participatory budgets were keen to start their own trials of push-pull. The participatory budgeting should mean that they know what the system involves and when they need to do particular activities and find necessary resources. Some farmers, mainly vegetable growers with smaller plots of land, decided that the system was not suitable for them. This also is a useful finding as it is far better to avoid wasting their time and resources on a system that will not help them and is not suitable. This would have resulted in disappointment and probably reduced trust in the extension and research staff involved.

Conclusions

The project has shown the challenges and value of multi-disciplinary research. The role of project leader must be clearly focused on the outputs to be achieved in order to fulfil the project's goals. Given this there is much synergism between researchers and the outputs also proved highly attractive for dissemination by extension and NGOs on both the livestock and crop sides.

Being multi-disciplinary, the project also highlighted the tendency of crops specialists and plant breeders to ignore the importance of secondary uses of crops such as maize for forage in parts of Africa.

The use of participatory budgets and plot mapping techniques was found highly beneficial in encouraging farmers to evaluate technologies such as the push-pull system, which necessitates a major change in the way these farmer manage their maize plots. The high level of interest shown indicates that many farmers wished to try out the system and, at the time of writing, some are already doing so.

Acknowledgements

This report is an output from research project R7955, IPM of maize forage dairying, funded by DFID Renewable Natural Resources Knowledge Strategy Livestock Production (LPP) and Crop Protection (CPP) programmes for the benefit of developing countries. The views expressed are not necessarily those of DFID.

Our thanks to the Director of KARI, Centre Director, Dr Gitonga, and the staff of KARI-NARC-Muguga, KARI-NARL Crop Protection Group for their support, and Ministry of Agriculture extension officers for their help and willing participation in our many activities.

References

Farrell G. 1998. The biology and ecology of *Ustilago kamerunensis* H Sydow and Sydow, a smut pathogen of Napier grass (*Pennisetum purpureum* Schum.) in Kenya. PhD Thesis, The University of Greenwich, UK.

Hans L X, Casler M D, Grau G C. 2001. Responses to divergent selection for fiber concentration at two disease potentials in smooth Bromegrass. *Crop Science* **41**:30-39.

Galpin C M, Shepherd D D, Dorward P T. 1999. *An Assessment of the Potential of Green Manuring for Wet Season Vegetable Production in Wenchi District, Brong Ahafo Region, Ghana, using Participatory Farm Management Methods.* Working report. Reading: The University of Reading (in conjunction with the Ministry of Food and Agriculture, Ghana), 39pp.

Gitau G K, McDermott C J, Omore J J, Odima A O, Mulei P A, Kilungo J K. 1994. Description of smallholder dairy farms in Kiambu District, Kenya. *Preventative Veterinary Medicine* 21:115-166**.**

Lukuyu, B.A. 2005. Effects of *maize streak virus* disease on yield and quality of forage of different maize cultivars. PhD thesis, The University of Reading, UK, 215 pp.

Mauricio R M, Mould F L, Dhanoa M S, Owen E, Channa K S, Theodorou M K. 1999. A semi-automated *in vitro* gas production technique for ruminant feedstuff evaluation. *Animal Feed Science and Technology* 79:321-330.

McIntire J, Bourzat D, Pingali P. 1992. Crop-livestock interaction in Sub-Saharan Africa. The World Bank, Washington D.C., USA.

Methu J N, Owen E, Abate A, Scarr M, Tanner J. 1997. Effect of offering three amounts of maize stover to dairy cows on intake and selection. In: *Proceedings of the British Society of Animal Science*, p. 85.

Murdoch A J, Njuguna J M, Lukuyu B, Musembi F, Mwangi D M, Maina J M, Kivuva B M, Mburu M W K, McLeod A. 2003. Integrated pest management options to improve maize forage yield and quality for small-scale dairy farmers in central Kenya. Pp. 71-77. In: *Crop Quality: Its Role in Sustainable Livestock Production. Aspects of Applied Biology* 70. Abberton, M.T., Andrews, M., Skøt, L. and Theodorou, M.K. (Eds.). The Association of Applied Biologists, Wellesbourne, Warwick**.**

Murdoch A J, Njuguna J M, Owen E. 2004. Report on Stakeholder Meeting, 2 April 2004. Strategies for feeding smallholder dairy cattle in intensive maize forage production systems and implications for integrated pest management. (DFID/NRIL Project R7955/ZC0180), 20 pp. School of Agriculture, Policy and Development, The University of Reading, UK.

Omore A, McDermott J J, Gitau G K. 1996. Factors influencing production on smallholder Dairy Farms in Central Kenya. In: Focus on Agricultural Research for Sustainable Development in a Changing Economic Environment. *Proceedings of the 5th KARI Scientific Conference, October 1996, Nairobi*. pp 370-380.

Onim J F M, Fitzhugh H A, Getz W R. 1992. Developing and using forages. In: *On-farm Research and Technology for dual purpose goats*. Editors Semenye, P. and Hutchcroft, T., Small Ruminant Collaborative Research Programme, Nairobi. pp 47-70.

Ride J P. 1983. Structural walls and other structural barriers in defense. In: *Biochemical Plant Pathology*, (Eds. J. A. Callow). Chichester, UK: Wiley & Sons.

Staal S, Chege L, Kenyanjui M, Kimari A, Lukuyu B, Njumbi D, Owango M, Tanner J C, Thorpe W, Wambugu M. 1998. Characterisation of dairy systems supplying the Nairobi milk market. International Livestock Research Institute, Nairobi.