LIVESTOCK PRODUCTION & CROP PROTECTION PROGRAMMES

Strategies for feeding smallholder dairy cattle in intensive maize forage production systems and implications for integrated pest management

R7955 (ZC0180)

FINAL TECHNICAL REPORT

1 April 2001 – 31 March 2004
(dissemination extension not reported here to 31 March 2005)

Dr Alistair Murdoch and Professor Emyr Owen

The University of Reading

Date completed: August 2004

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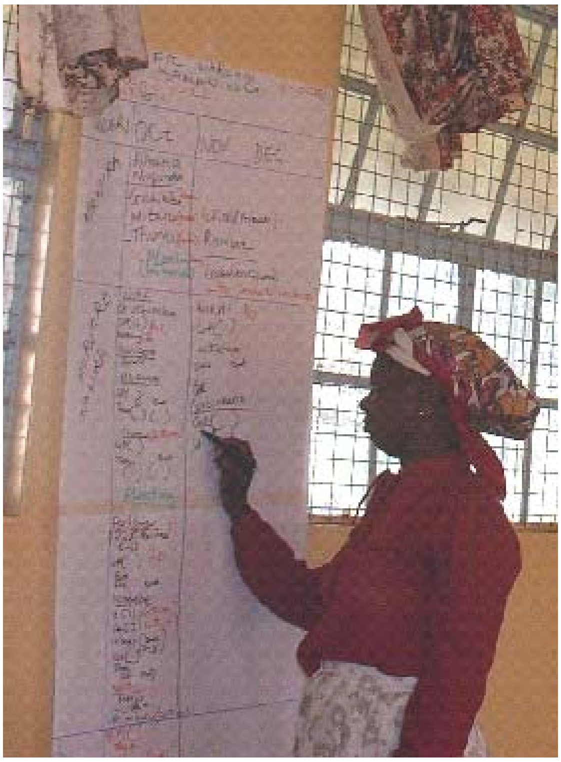

Clockwise from above: Stall-fed dairy cow; stalkborer damage; maize head smut; participatory exercise with Kamari womens' group at FTC Waruhiu; infecting maize with *maize streak virus*; weedy plots in front with stunted maize and non-weedy plots behind; *maize streak virus* disease.

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Contents

Background and objectives

1.1 Background to the project

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).

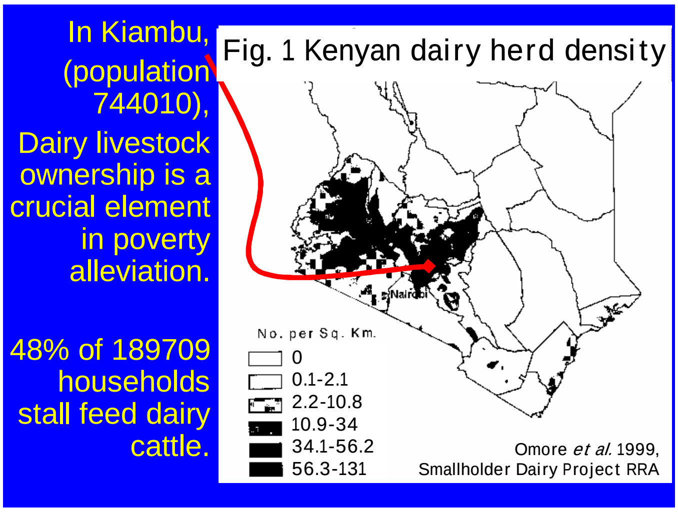


Fig. 1 Kenyan dairy herd density

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 (Fig.1; Staal *et al.*, 1997). Dairy animals are fed in zero-grazed or semi-zero-grazed systems (Fig. 2), 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 744010, 48% of 189709 households stall feed dairy cattle, so that dairy livestock ownership helps alleviate poverty for many (Fig 1). Farming in this area is becoming more intensive as pressure on the land rises 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 (Miano, pers. comm.). 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 to 50% of the area is occupied with forage/maize. The project’s RRA 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. 3, McLeod *et al.*, 2001).

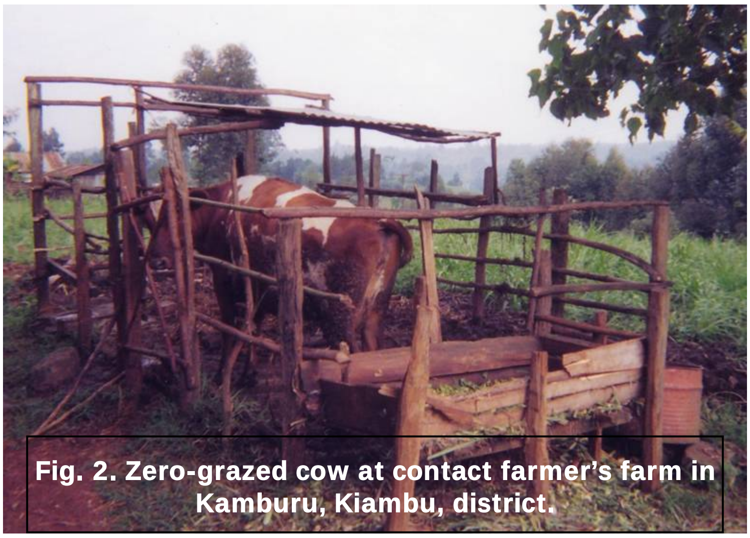


Fig. 2. Zero-grazed cow at contact farmer’s farm in Kamburu, Kiambu, district.

However, forage (in the form of maize thinnings and leaf strippings, weeds and forage crops such as Napier grass) is only abundant during the rainy seasons. Just over 50% of farmers

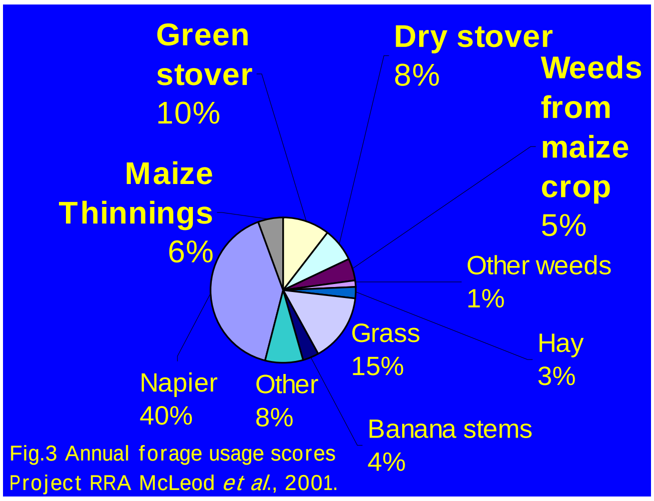


Fig.3 Annual forage usage scores Project RRA McLeod *et al.*, 2001.

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 (see for example Fig. 4) 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, will thereby improving the amount of forage available and in turn will 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.


Fig. 4. Storing dry maize stover for use in the dry season


Fig. 5. The project aimed to integrate control of different biotic constraints on maize – e.g. weeds and MSVD as shown here.

A survey of the Central Highland Region found that localised, but often severe, epidemics of diseases are present at levels likely to reduce yields (Farrell *et al.*, 1999). The most important biotic constraints to production include: northern leaf blight (*Exserohilum turcicum*), *maize streak virus* disease (MSVD), rust (*Puccinia* spp.), anthracnose (*Colletotrichum* spp.), Fusarium foot-rot and stem borer (G. Farrell, KARI/DFID NARP2, Crop Protection Project, pers. Com.). In the disease survey, MSVD is singled out as being the most common and potentially damaging of the diseases in the Kiambu District. Weeds infesting maize crops (and non-cropped vegetation in adjacent land), whilst providing a measurable source of animal forage (Onim *et al.*, 1992), directly reduce yields in maize. Conversely, Napier and *Desmodium uncinatum*, when grown in association with maize, reduced the incidence of stem borer (*Busseola fusca*) by repelling the adult insects then trapping the larvae (Khan *et al.*, 1997). Therefore, the negative and positive contributions of weeds and planted vegetation (ie Napier and cover crops) to livestock production must be integrated within the context of pest, disease and weed management (Fig. 5).

The need for improved livestock nutrition has been shown in numerous recent surveys of Central Kenya. In particular, the findings of a recent KARI survey of Central Kenya showed that poor nutrition was one of the most important constraints to milk production (Omore *et al.*, 1996). This, along with increasing population which is causing increased intensification of farming means that the quantity and quality of forage is of utmost concern to the dairy farmer in this region. In addition, it is the poorer farmers who are more reliant on maize for forage than Napier grass (KARI/MoA/ILRI Smallholder Dairy Project). Therefore, efforts to increase the production of maize will be of particular benefit to resource-poor smallholders.

1.2 Researchable constraints

Since 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 first of all to investigate the impact of *maize streak virus* disease and weeds on forage yield and quality. Some evidence from Uganda implied that while early infection with MSVD decreased grain yields in small plot experiments with artificial infection, on-farm studies with natural infection did not show the same impact of time of infection. Reasons for this anomaly need researching to confirm the impact of MSVD on yields.

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.

In more detail, researchable constraints included the following:

- *Maize Streak Virus* Disease (MSVD):
    - Impact of MSVD on maize forage yield and quality, and grain yield
        - Farmers' perceptions
        - Effect of time of MSVD infection on resistant and susceptible varieties
        - Effect of MSVD incidence (%plants infected) on ability of susceptible cultivars to overcome disease
        - Interaction with fertility and maize planting density
        - Control using MSVD resistant cultivars
    - Seasonality of MSVD under farm conditions
    - Effect of delay in planting date on severity of disease

- Weeds:
    - Impact of weeds on maize forage yield and quality, and grain
        - Farmers' perceptions
        - Effect of time of second weeding and of different chemical and non-chemical weeding regimes to control weed impacts
        - Competition for light and water
    - To what extent do farmers delay weeding in order to use weeds as forage?
        - Do such delays affect forage or grain yields and quality of maize thinnings and stover?

- Use and quality of "weeds" growing in maize as forage

- Do weeds affect incidence of MSVD?

- Interaction with livestock: Do cattle contribute to dissemination of weed seeds and teliospores of maize head smut in manure?

- Maize stalk borer: the ability of the push-pull habitat management system to reduce stalk borer infestations in Kiambu and to alleviate forage shortages

- The economics of ensiling excess forage produced during the rainy seasons to alleviate forage shortages in the dry seasons.

1.3 Evidence for demand

DFID Kenya Country Strategy Paper 1998-2002 states that Britain will "seek to develop and implement innovative approaches in areas such as sustainable agriculture…." in order to "improve productive opportunities and living conditions of the rural poor" (p 16). Smallholder dairying, as an important source of income for resource-poor smallholder households, is recognised by both KARI and ILRI who have targeted smallholder dairying as their primary research priority. Recent work carried out by KARI/MoA/ILRI in the Central Highlands Region has shown that maize-based crop-livestock systems are becoming increasingly intensified as demand for land increases. Remarkably, crop protection issues have not been a high priority for the Kenyan maize improvement programme. However, a survey of maize diseases which began in 1994 by the KARI/DFID Crop Protection Project reported that *maize streak virus* is a major problem in the Kiambu District, Central Highlands Region: 95% incidence with severe damage was reported in one of the Divisions sampled. A not atypical example from Kiambu is shown in Fig. 6. The increasing importance of maize diseases and pests was confirmed at a stakeholders' meeting, held at KARI in December 1998. For farmers, this lack of emphasis on crop protection issues was reflected in the fact that disease resistance did not feature at all in the criteria used in selection of maize cultivars (Table 1).

Fig. 6. Farmer's field devastated with MSVD. Kiambu 2001/2, short rains.

Table 1. Reasons for choosing maize cultivar by farmers monitored in the project's longitudinal study in short rains 2001 and long rains 2002. (See McLeod *et al.*, 2004 for sampling and survey details)

Reason for choice	Short rains	Long rains
Cheap	1	3
Drought tolerant	2	2
End of last years bag	3	
Experiment		3
Free gift	4	1
KARI field day		1
Matures fast	1	6
Matures fast. Yield forage		1
Only one available	2	2
Performance for neighbour	3	
Previous performance	13	3
Previous performance. Yield forage		2
Previous season rain failed		
Recommendation - extension		2
Recommendation - seller		1
Seed from shop not good	1	
Spread risk	3	
Suitable	5	2
Yield forage	1	
Yield grain	1	5
Yield grain and forage		12
Total	40	46

Peformance and yield were clearly major criteria, and these may reflect disease resistance. Nevertheless at the start of this project, there was a total lack of cultivars resistant to MSVD in the Kenyan market place – in marked contrast to, for example, Uganda. Not surprisingly, therefore, our preliminary survey showed that MSVD was not only the with the greatest perceived impact on stover (Fig. 7) and grain (data not shown – see McLeod *et al.*, 2001) yields in Kiambu, but also the one farmers found it most difficult to control (Fig. 8). Fields planted with expensive hybrid seeds of susceptible cultivars are therefore not surprisingly sometimes totally devasted with MSVD.

The importance of MSVD as a constraint to maize production has been reported from many countries such as Kenya (Guthrie, 1978) with yield losses of 24 –63%, South Africa (van Rensburg, 1981) -50% losses, Zimbabwe (Mzira, 1984) recorded 36% losses, Democratic Republic of Congo (Vogel et al. 1993) recorded 6.5-8.9 kg/ha for each additional 1% increase in incidence of infected plants, Nigeria and other West African countries (Fajemisin et al., 1976 up to 100% losses) and (Bosque-Perez 1998 losses between 17 -71%). However, in all these studies on effect of MSVD have primarily focused on yield losses of grain while totally ignoring forage yield. Fields such as that shown in Fig.6 will yield little or no grain and will only be useful as forage.

The demand for resistant cultivars was therefore clear in stakeholder meetings and palpably tangible at farmer field days where resistant and susceptible cultivars were planted alongside one another.

Fig.7 Farmers' perceptions of the impact of pests and diseases on stover yield in Kiambu. (From Project's RRA – McLeod *et al.*, 2001). Farmers were asked to score impact on a scale of 1 (low) to 5 (high).

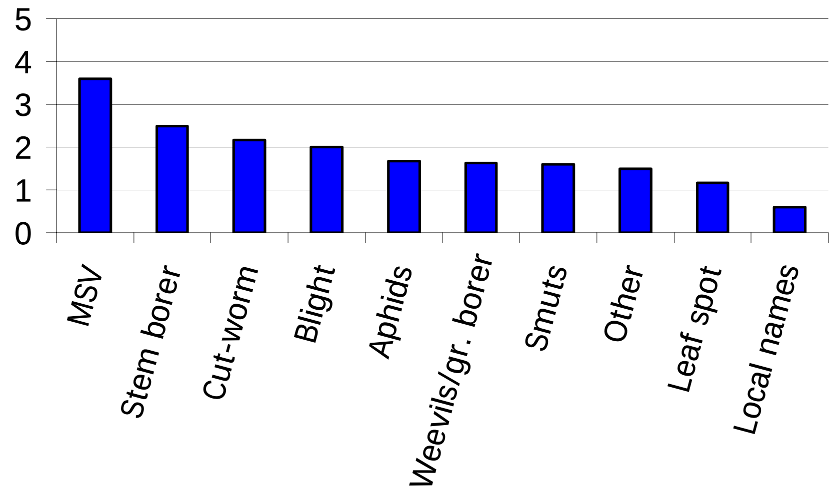
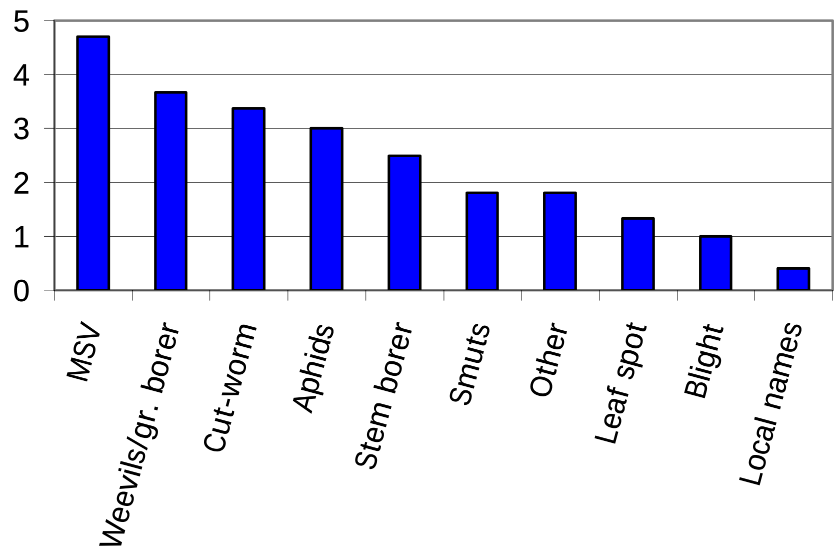


Fig.8 Farmers' perceptions of the difficulty of controlling specific pests and diseases in Kiambu. (From Project's RRA – McLeod *et al.*, 2001). Farmers were asked to score difficulty on a scale of 1 (easy) to 5 (hard).



Impacts of uncontrolled weeds on maize grain yields are equally well known including in sub-Saharan Africa (Marnotte, 1997). Traditional weed control is mostly handweeding, which constrains timeliness especially in early crop growth stages, which are particularly critical to prevent yield losses later in the season in crops such as maize. Herbicide spraying treatments require much less labour: i.e. 1 person day/ha compared to 10-20 person days/hectare for manual treatment (Marnotte, 1997). Despite these potential labour savings there has not been widespread adoption of herbicide technology in maize-based farming systems. The main focus of this research is to examine the impacts of specific weeding regimes on maize forage yield and quality.

2 Project purpose

- Performance of livestock in high potential and peri-urban intensive farming system improved (LPP)
- Develop and promote strategies to improve the seasonal availability of livestock feed (LPP)
- Benefits to poor people generated by application of new knowledge on crop protection to maize-based production systems (CPP)
- Strategies developed and promoted to reduce the impact of pests on poor peoples' crops and to improve quality and yield from maize-based systems (CPP)

The objectives are to assess first of all the impacts (biological, socioeconomic, management) of maize streak virus and weeding regimes on the seasonal availability of forage in smallholder dairying, and secondly, the implications for integrated pest management of feeding or composting diseased forage and weeds. IPM options were also tested to mitigate effects of pests, weeds and diseases.

3 Research Activities

The locations, agro ecozones and soil types of the places in Kiambu district where research was conducted are shown in Figures 9-10. The overall location of Kiambu in Kenya can be seen in Fig.1.

3.1 Rapid Rural Appraisal (Logframe activity 1.1)

Given the work that has already been done on both maize and dairy cattle in the project area, the team felt that the most useful addition to knowledge would come from the interaction between the maize crop and the dairy system, in particular the times of year when weeds, thinning and stover were most important and whether weed, pest and diseases control practices appeared to be affected by considerations about the availability of forage. Previous and ongoing studies have focussed on either one of the systems, not both at the same time.

The appraisal was carried out in Kiambu district during April and May 2001. Rainfall in the district is bimodal and the long rains normally begin at the end of April or beginning of May. The study comprised two interviews with each of ten farmer focus groups (Fig. 9). Groups consisted either of existing formal or informal groups within the study communities, or farmers from the community who were interested in attending the meetings. The sample of villages was chosen purposively to represent areas of high and low maize streak virus disease incidence, different production systems, and differences in resource endowment. Production systems were coffee-dairy, maize-dairy, vegetable-dairy and tea-dairy. Maize was grown in all systems. Within Kenya a number of these agro-ecozones have been identified (initially by Jaetzhold and Schmidt, 1983; see Fig. 10), where most smallholder farms in an area will include enterprises dictated by rainfall, temperature and in some cases influence of a major producer providing a market, such as a large tea estate. Lower resource endowment was represented by a drought prone area with limited access to the Nairobi milk market (Thigio), a village where many small farmers were known to rent land from larger farms (Kawainda), and a village where plot sizes were very small and some farmers were squatters. Further details are in the report of the study (McLeod et al., 2001).

3.2 Longitudinal Study (Logframe activity 1.3)

Three communities were studied: Kamburu, Kiairia and Muthure (homesteads are shown by dots on Figs 9-10). Kamburu, a tea growing area, was higher and wetter than the other two and rainfall was sufficient for maize to be grown almost continuously. Kiairia was a coffee-growing area, drier than Kamburu and with two clear rainy seasons - short rains (beginning Sept./Oct.) and long rains (beginning May/June) which delimited the maize cropping seasons. Muthure also had two clear rainy seasons. It was the closest community to Nairobi and many farmers also grew vegetables for sale.

Eight farms were studied in each community, making a total of 24. Records were kept over two consecutive cropping seasons, namely the short rains season in 2001 and the long rains 2002. When first selected, four farms had cattle and four did not in each community, but by the time the baseline data were collected, some had acquired cattle.

Each farm might be made up of one or as many as three plots, where a plot was defined as a continuous farmed area. The plot on which the farmhouse was situated was designated the “homestead plot”. Of the 24 study households, four had more than one plot. Each plot was divided into patches on which different crops or combinations of crops were grown. The aim was to study up to three patches on the homestead plot on which maize was grown. If the homestead plot had no maize or was divided into very small patches, another plot would be chosen. Farmers in Kiambu often practice rotation on their patches rather than growing continuous maize, so it was necessary to study a different sample of patches in each season. Within the chosen plot, up to three patches were chosen. The largest patch with maize was chosen first. If there were more than one maize patch two more were chosen at random. If there were less than three maize patches, another patch with a different crop would be chosen at random. Results are available for 32 and 47 patches of maize in the short and long rains, respectively.

The aim was to make four visits to each community, at times approximating to the crop stages of first weeding, second weeding, late tasselling and dry harvest. These times

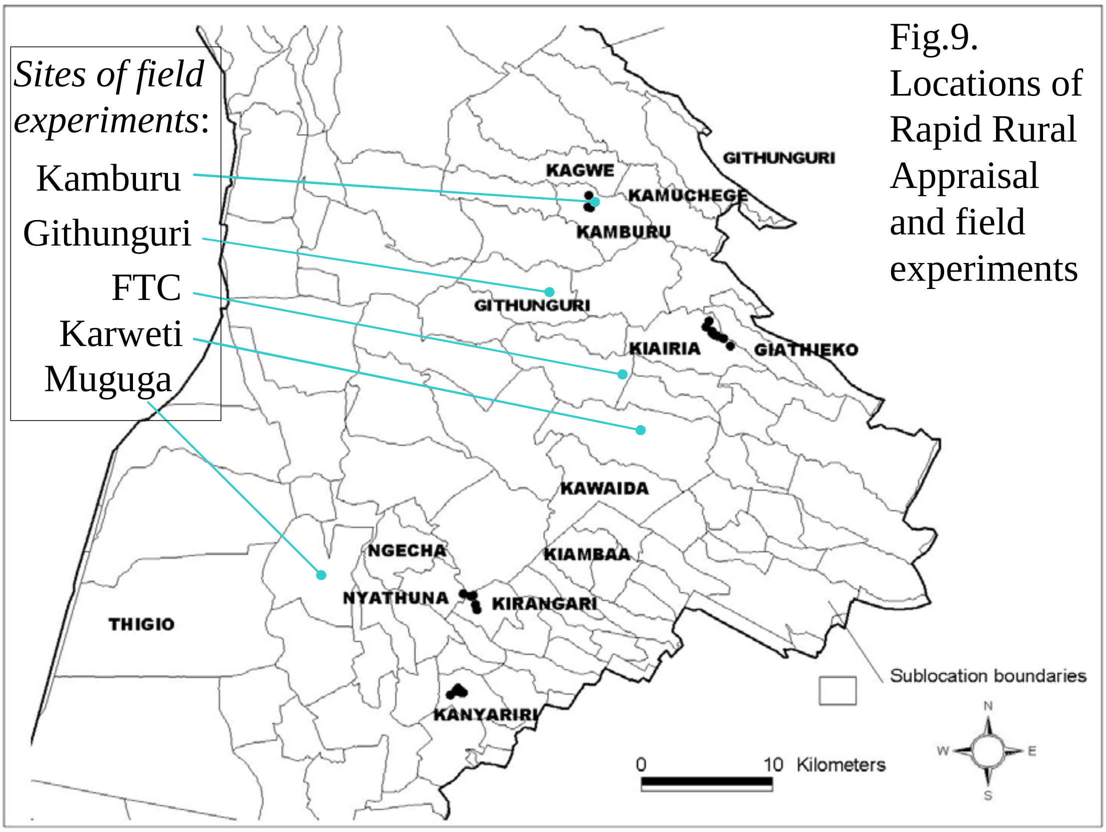


Fig.9. Locations of Rapid Rural Appraisal and field experiments

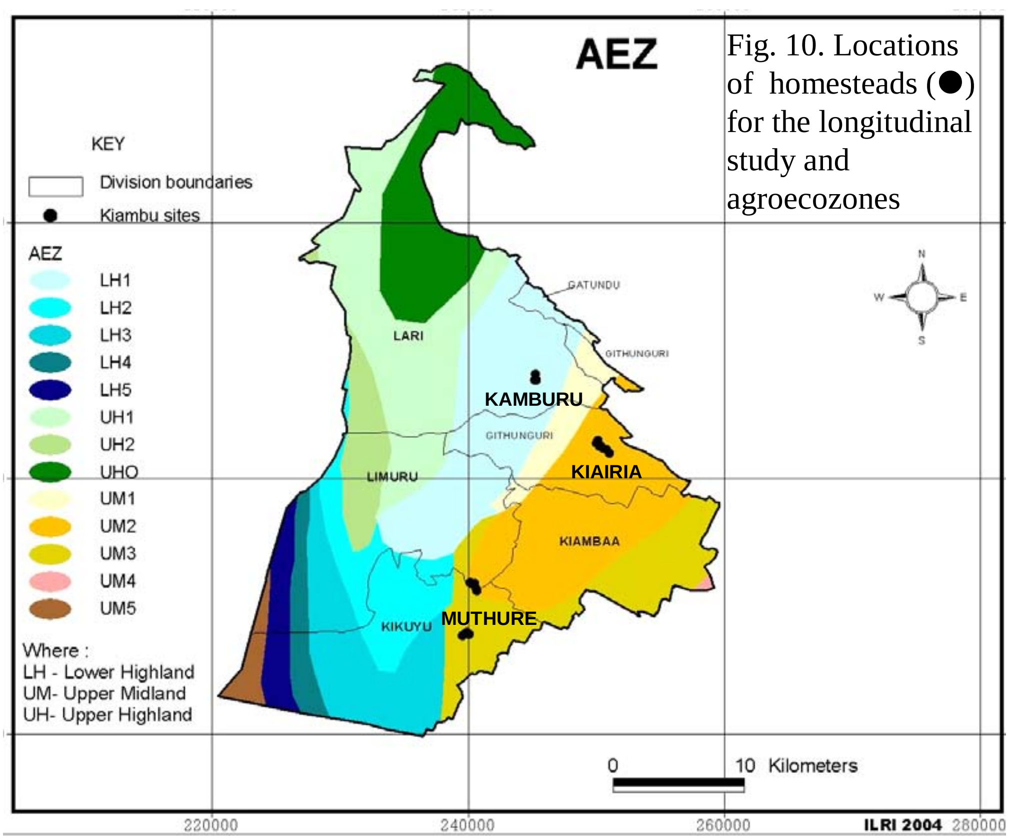


Fig. 10. Locations of homesteads (●) for the longitudinal study and agroecozones

were considered optimum to observe progress of MSV, presence of flowering weeds and use of crop thinnings.

Three questionnaires were administered, and two members of the study team, a biologist and a socio-economist, visited each household on each visit. Copies of questionnaires are included in the report on this study (McLeod *et al.,* 2004).

3.3 On station and on-farm research on MSVD (Logframe activities 1.4, 3)

Table 2. Summary of experiments carried out on MSVD and variables investigated. On-farm studies were near Githunguri. Others were either at KARI-NARC-Muguga or FTC Waruhiu (Fig. 9).

	2001 Short	2002 Long	2002 Short	2003 Long
Infection time	√	√	√	√
Infection level	√	√		
Cultivar	√	√	√	√ on farm
Planting date			√ on farm	√ on farm
Planting density		√	√	
Fertiliser	√	√	√	

Field experiments were carried out over four growing seasons including a wide range of treatments (Table 2). Materials and methods for most of these studies are included in Lukuyu *et al.* (2005a, b). Draft copies of materials and methods from these papers are included in Appendix 2.

3.4 Field experiments on weeds (Logframe activities 1.4, 3)

Experiments on weeds extended over five growing seasons at three sites (Table 3, Figs 9-11) and including a variety of weeding regimes.

Table 3. Summary of experiments carried out on weeding regimes

	Short 2001	Long 2002	Short 2002	Long 2003	Short 2003
Muguga	☑	☑	Times† & seed bank	…	
FTC Waruhiu			☑	☑	Times only ‡
Kamburu (on farm)			☑	☑	

† Hand weeding times for both 1st & 2nd weedings
‡ Hand weeding times for 1st weeding only

Table 4. Weeding regimes tested

Muguga	Weed free control Weedy (i.e. unweeded) control Herbicide Handweeded 2 and 6 weeks after planting
FTC Waruhiu	Weedy control Herbicide – whole plot Herbicide – inter-rows *only* Handweeded 3 & 8 weeks after planting Handweeded 3 & 10 weeks after planting
Kamburu (on farm)	As FTC Waruhiu *Except no weedy control*

3.5 On station and on-farm research on transmission of spores of maize head smut and weed seeds after feeding to cattle and composting of manure (Logframe output 2; activity 2.1)

During the 2002/3 short rains season, experiments were conducted to determine if maize head smut spores (*Sporisorium reilianum*) and seeds of five weeds are dispersed through cow manure and if composting the dung would be a feasible option to eliminate these fungal spores and weed seeds. The experiment was conducted using three Friesian steers each weighing approximately 700 kg. The animals were fed on Napier grass for one week before being put on the ration containing smut spores and weed seeds. The dung collected before this contaminated ration was administered served as a control. 250 g of smut teliospores and 250g of seeds of each of five weed species were mixed with 400 g mixture of maize germ, bran and molasses. The weed species comprised *Amaranthus* spp., *Bidens pilosa*, *Erucastrum arabicum*, *Galinsoga parviflora* and annual grasses.

This ration was given to each of the three steers daily for a period of 3 weeks. Additionally the animals were fed on 100 kg of chopped Napier grass. Dung was collected daily from the three steers and pooled and then split into two portions. One portion was put into a compost pile and composted for three months. The compost heap was mixed with chopped dried maize stover to facilitate aeration. The volume of maize stover was about 5% of the total. The second portion was spread on the floor to dry for use as dry manure. Additional batches of smut spores and weed seeds contained in a small polythene bag were incubated in the centre of compost heap at a depth of 30 cm. Survival of teliospores in the compost and dried manure was assessed in the glasshouse by planting seeds of a susceptible maize cultivar in pots containing steam sterilised soil mixed with the various treatments. This glasshouse experiment was a completely randomised design with 21 maize seeds planted in each pot of each of the following treatments replicated in five pots.

- Fresh cow dung from smutted ration.
- Dried cow dung from smutted ration.
- Composted cow dung from smutted ration.
- Smut teliospores incubated in compost for three months.
- Fresh teliospores stored in refrigerator (positive control).
- Steam sterilised soil alone (negative control).
- Dried cow dung before treatment (spore free dung - negative control).

The weed seeds were allowed to “extract themselves” by mixing with compost and allowing the seeds to emerge over a period of six months. Emerging seedlings were counted and removed periodically.

3.6 Farmer participatory studies on push-pull and forage conservation (Outputs 3 and 4)

Two farmer groups participated, namely, the Kamari women's group meeting at Waruhiu FTC and the Karweti farmers' group who used one member's land in Githunguri.

During the long rains 2003 planting season each group planted Push-pull & control plots. Inputs and outputs were recorded during that and the following short rains. Treatments and management were under control of the farmer groups who carried out the studies as follows. The initial participatory protocol is in Appendix 4 and the outcome of that process in terms of farmer participatory research is shown below. This study was funded by the add-on to project R7955 in Autumn 2002, allowing establishment of the plots in the long rains 2003 and a second season in the short rains 2003/4.

Results must only be treated as an indicative case study. Due to the timescale in terms of project funding, the process had to be concluded after only two seasons in March 2004. The crop rotation currently practised by the farmer groups (cf. Appendix 4) and the time required to establish the push-pull plots means that four seasons are really needed to evaluate the system. The first season was needed to establish the Napier and *Desmodium*. In the second (short rains) season the farmers grow some maize but other crops are also important. No replication was feasible (plot sizes are approx. 30x30 metres – maize patches in Kiambu are not usually bigger than this). Fertility gradients came to light between control and push-pull plots and so comparisons between plots need to be treated with caution. Moreover, in the nature of participatory research, the two farmer groups chose to do things slightly differently and so comparisons between sites cannot be made easily. Some mistakes were also made in establishing the plots (the *Desmodium* was planted instead of a row of maize rather than as a true intercrop).

In spite of these caveats, the farmers were all enthusiastic about the process and the technology largely because of its benefits in terms of forage production, and the control of stem borers is a bonus rather than the main reason for adoption.

Kamari

Plot area = approx 900m²

Two maize varieties planted

H511 and Pan 67 @ 450 m² each

Perimeter = 3 rows Napier

Intercropping – push-pull plot: beans and Desmodium in alternate interrows

Intercropping – control plot: beans in every interrow

Spacing for maize = 75cm x 30cm

Seeds per hill – 3

Manure rates - 340 grams per hill

Fertilizer rates - 0.40 grams per hill

Karweti

Plot area = approx. 900m² in push-pul plot and 670 in control

Two maize varieties planted

H511 and Pan 67 @ 450 m² each in push-pull

H511 @ 400 m² and Pan 67 @ 270 m² in control plot

Layout similar to one described for Kamari except

Spacing for maize = 75cm x 60cm

Manure rates - 106 grams per hill

Fertilizer rates -1.65 grams per hill

3.7 Training and dissemination activities (Logframe Output 4)

See Report of Stakeholder meeting dated 2 April 2004 for details (Appendix). Reports on the various individual activities are included as appendices.

4 Results

4.1 Rapid Rural Appraisal (Output 1)

A separate report is available (McLeod et al., 2001) and some of the graphs presented in this report (e.g. Figs 3, 7, 8) are revised from that report. The most important points can be summarised as follows:

1. Forage was confirmed to be in shortest supply in the dry season of January to March each year. The maximum impact of this project on rural livelihoods and on milk yields and quality may therefore come from alleviating forage shortages at this time of year.
2. *Maize streak virus* disease (MSVD) was confirmed to be the main biotic constraint to maize grain & forage production in the Kiambu district followed by stem borers. Early MSVD infection causes total yield loss and necessitates replanting. A strategy for early control taking account of the epidemiology of MSVD is essential.
3. Farmers were generally unaware of MSVD epidemiology and did not know how to control it. The wide range of planting dates and relay cropping may be encouraging disease spread. Resistant cultivars were not generally available in Kenya and have only become so in 2003/2004.
4. The maize crop is weeded twice. The first weeding occurs at an early stage of the crop and is vital to prevent competition, while the second weeding may be delayed to allow larger weeds for feeding to livestock. Farmers are well aware of weeds suitable for feeding to their livestock. Although viewed by farmers as important, weeds do not contribute a large volume of forage.

4.2 Longitudinal Survey (Output 1)

A separate report is available (McLeod et al., 2004). This study was conducted to provide supporting evidence especially on trading and values of forage for the rest of the project and so some of the graphs and tables are reproduced at various points in this report. The most important points can be summarised as follows:

1. No Maize streak virus disease (MSVD) resistant maize cultivars were grown and disease resistance did not feature in the reasons why farmers chose specific varieties. The local landrace, Gikuyu, was however grown and in this and other studies of this project, showed some tolerance to MSVD. Hybrids H513 and H614 were not only the most popular cultivars, but also had the highest incidences of MSVD. Prices paid for H614 were 130 KSh/kg in SR and 135 in LR.
2. MSVD was the most important pest and/or disease problems followed by stem borers. Most significantly given the greater impact of early infection with MSVD on forage and grain yields, 21/32 and 43/47 patches were already infected with MSVD by the normal time of the first weeding, in SR and LR, respectively. Relay and delayed planting may increase MSVD and a wide spread of planting dates was a particular feature in

Kamburu. Contrary to expectations therefore, the incidence of MSVD in Kamburu was actually lower than in Kiairia.

3. Stem borers affected 13/32 and 25/47 patches in SR and LR, respectively.

4. Control of pests and diseases was rarely carried out except that significant numbers of farmers deliberately fed parts infected with stem borers and MSVD to their animals.

5. Weed management (in all but one case by hand and usually by women) failed to prevent seed production – flowering weeds were present at planting as well as at both first and second weedings. At the normal time of the second weeding, weeds were flowering in 20/26 and 18/30 patches in SR and LR, respectively. The second weeding was also often delayed or not done systematically – weeds either being removed late or only selectively hand-pulled for feeding to livestock. Main weed species in both seasons were Bidens pilosa, Galinsoga parviflora, Commelina spp. and Tagetes minuta. Flowering weeds of the first three species mentioned and of Amaranthus spp. were commonly fed to livestock.

6. The use of manure and fertiliser was of interest due to the possibilities of (a) dissemination of weed seeds and spores of maize head smut disease in manure and (b) an impact of fertility on weed and disease problems. Fertiliser was used in 22/32 and 37/47 patches in SR and LR, respectively. Significant numbers of patches do not, therefore, receive fertiliser. Manure was applied to 23/28 patches in SR and 37/43 in LR, 24 of the latter also receiving fertiliser. Surprisingly, 70-80% of patches were manured whether or not the farmers had cattle and the use of fertiliser was actually more likely where farmers had cattle. In terms of risks of disease and weed transmission for which farmers may have no knowledge, the main point was that the manure for 10/32 patches in LR was sourced off-farm. Such patches would warrant more careful monitoring for new weeds and maize head smut.

7. Farmers with cattle were much more likely to thin their maize patches and thinnings were widely used to feed cattle. Forages were sourced on farm 90% of the time. Maize thinnings and green maize stover were valued from 25-70 KSh and mostly at 50 KSh per "human load" (perhaps 40kg). Thinnings were sometimes infected with MSVD, but the view of most farmers was that MSVD on the thinnings did not affect price per human load – (though the number of loads per unit area is likely to be lower). Mean number of human loads of green stover per ha was 137 (on 29 patches), valued at 6877 KSh/ha. Dry stover was fed in 12 cases, yielding from 29-776 human loads per ha.

4.3 MSVD research (Outputs 1 and 3)

Results of the MSVD research have been published in various conferences and a comprehensive report of the main results and conclusions is available in the Stakeholder Meeting Report (Presentation by Lukuyu in Murdoch *et al.* 2004)*.* The complete report on this work is still pending completion of a PhD Thesis by Mr B. Lukuyu, provisionally entitled *The effects of maize genotypes and* maize streak virus *disease (MSVD) on maize forage, grain yield and quality*. A copy of the thesis will be available after submission and examining (expected February 2005). The main bulk of the thesis is currently being prepared in the form of four scientific papers. In advance of the thesis and these publications in refereed journals, it is emphasised that the analysis of the results presented here is still incomplete and will remain so until accepted for publication elsewhere.

4.3.1 Disease surveys

Maize streak virus disease (MSVD) was ranked in 2001 by Kiambu farmers as their most intractable pest/disease problem (Fig. 8) and the one which they perceived to have the greatest impact on yields of forage (Fig. 7) and grain from their maize crops as reported in the project's Rapid Rural Appraisal (McLeod *et al*., 2001).

Table 21. Pests and diseases reported in monitored maize patches of the three communities (Kamburu, Kiairia and Muthure) in the longitudinal study in A) short rains 2001 out of 32 patches and B) long rains 2002 out of 47 patches.

A)	Number of maize patches in each community			
Pest/disease at 1st weeding	**Kamburu**	**Kiairia**	**Muthure**	**Total**
MSVD	7	7	7	21
Stemborers	5	3	5	13
Smuts	3		1	4
Turcicum blight	1			1
Cutworms			1	1
Total	16	10	14	40
Pest/disease at 2nd weeding				
MSVD	5	7	4	16
Stemborers	4		5	9
Smuts	2		3	5
Rat		1		1
Total	**11**	**8**	**12**	**31**

B)	Number of maize patches in each community			
Pest/disease at 1st weeding	**Kamburu**	**Kiairia**	**Muthure**	**Total**
MSVD	10	19	14	43
Stem borers	6	8	3	17
Turcicum blight	5	9	3	17
Grey Leaf Spot	1			1
Total	**22**	**36**	**20**	**78**
Pest/disease at 2nd weeding	**Kamburu**	**Kiairia**	**Muthure**	**Total**
MSVD	12	18	14	44
Stem borers	4	12	9	25
Turcicum blight		2	1	3
Cutworms		2		2
Grey Leaf Spot	2			2
Rust	1			1
Crop dried	1			1
Total	**20**	**34**	**24**	**78**

Over 60% (21/32) and 90% (43/47) of patches had been infected by MSVD just after the first weeding in short and long rains seasons, respectively, more than the total observations of all other pests and diseases reported (Table 2A,B).

Data on MSVD incidence were also collected during the long rains 2002 season. "Incidence" was estimated in each maize patch by examining at least 500 plants in a sample area at the time of the visit and calculating the proportion of plants showing infection. If no plants were removed or thinned out this would show the number of plants infected from emergence to the time of visit. In the study, there were two cases where diseased plants may have been removed and fed to animals, reducing the apparent incidence. No MSVD resistant maize cultivars were being grown and disease resistance did not feature in the reasons why farmers chose specific varieties as reported in the project's Longitudinal Study (McLeod et al., 2004; Table 1). The actual disease incidences varied between varieties of maize being grown (Table 3). The local landrace, Gikuyu, showed the lowest mean incidence (6%) which may imply some tolerance to MSVD although the number of patches being monitored was small. Incidences were highest in the popular hybrids (H500 and 600 series) which are known to be susceptible to MSVD.

Table 3. MSVD incidence from planting to first weeding in different cultivars, long rains 2002 (From McLeod *et al.* 2004).

Cultivar of maize	Mean MSVD incidence	Sample size
Local	0.06	7
Pioneer	0.17	2
Other hybrid	0.35	3
H614	0.52	15
Mixed	0.55	5
H513	0.58	5

The responses to each pest and disease problem was also recorded and for MSVD the reaction in the vast majority of cases was to "do nothing", although some removed infected plants to feed to their animals.

In terms of economic analysis (for project output 3), the latter response to MSVD was of interest as a major question was whether thinnings infected with MSVD would be rejected or be less valuable.

In the 2002 long rains, prices were obtained for green maize stover 14 times and thinnings 9 times. In all except one case these were based on the farmer's knowledge of the market price rather than an actual purchase. Prices given were the same for stover and thinnings – in 20 cases, KSh 50/- per human load (c. 40 kg) and in 3 cases, KSh 25/ to 50/ per load. For stover, this was slightly lower than the price of KSh 70/- suggested during the 2001 short rains.

No MSVD data were available for the short rains season. In the long rains, there was very little information on the level of MSVD infection in forage purchased or sold. However, 23 farmer responses from 11 farmers stated that the price of traded forage was not affected by the extent to which it was infected by MSVD, and no farmer contradicted this (From McLeod *et al.* 2004). Clearly, however, more plants would be needed to make up a load if the plants were stunted with MSVD. So the price per plant would be affected, but per traded unit, MSVD had no effect.

4.3.2 Effects of infection with *maize streak virus* on yields of maize forage and grain

Effect of time of infection

In the 2001 short rains, infection with MSV 14 days after crop emergence reduced the yield of thinnings ($p<0.001$; Fig. 11A, 12A) and grain ($P<0.05$; Fig. 11G, 12G). With respect to stover yields, the interaction of time of infection and cultivar was significant such that there was a reduction in stover yield with early infection but this effect varied with cultivar ($P<0.05$; Fig. 11D, 12D). Conversely, later infection, 35 or 56 days showed little difference from the uninfected control in forage (thinnings and stover) or grain yields (Figs 11 A, D, G). Infecting the crop at 14 days after emergence reduced the thinnings DM yield by 29% compared to the control (Figure 12, A - C).

In the 2002 long rains, the greatest reduction in yield of forage (thinning and stover yields; $P<0.001$) and grain ($P<0.05$) was again for plants infected 14 days post-emergence (Fig. 11 B, E, H). In the 2002 short rains, only the 14 days infection was tested. In this season, thinning and stover yields were significantly ($P<0.001$) reduced by the effect of MSVD while grain yield was not affected. However, there were significant interactions of time of infection and cultivar for stover and grain yield (Fig. 11 F, J).

Figure 11 - Yields (dry matter in t/ha) of maize thinnings (A-C), stover (D-F) and grain (G-J) in 2001 short rains (A,D,G), 2002 long rains (B,E,H) and 2002 short rains (C,F,J) at KARI-NARC-Muguga. All experiments included MSVD resistant (KH521 in 2001, PAN67 in 2002) and susceptible cultivars (H511 in short rains; H614 in long rains) plus the local landrace, Gikuyu (2001 short rains and 2002 long rains). Seed of the latter was obtained from local farmers, the hybrids from the breeder or certified sources. Experimental designs are shown in Appendix 2a. Yields are only shown separately for each cultivar where there was some evidence that the cultivars were responding differently to time of infection (i.e. usually a significant ($P<0.05$) interaction of cultivar and time of infection in ANOVA). Otherwise mean values are shown. All plants were infected except for the uninfected control shown which is plotted as though it were infected on the harvest date.

Short season 2001 **Long season 2002** **Short season 2002**

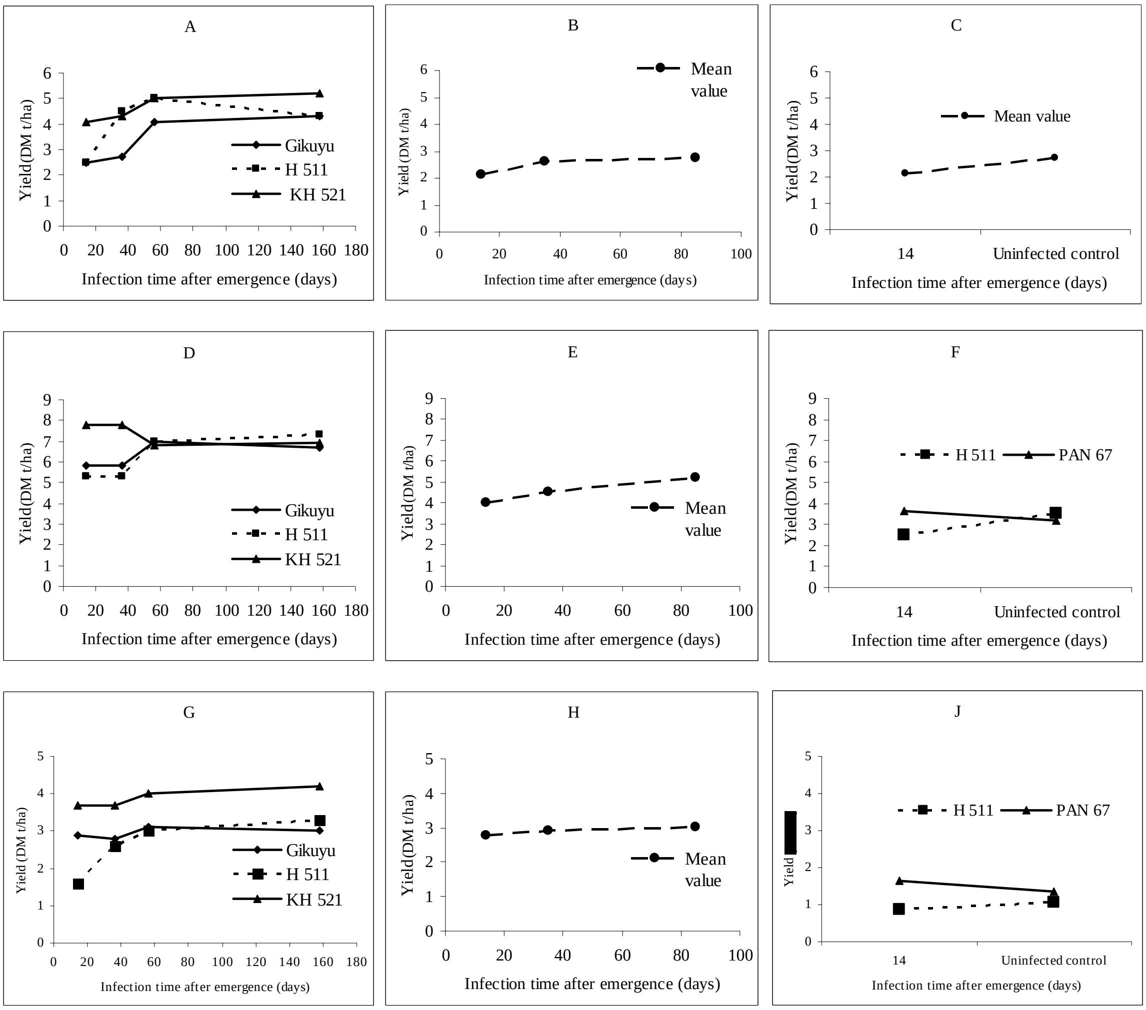
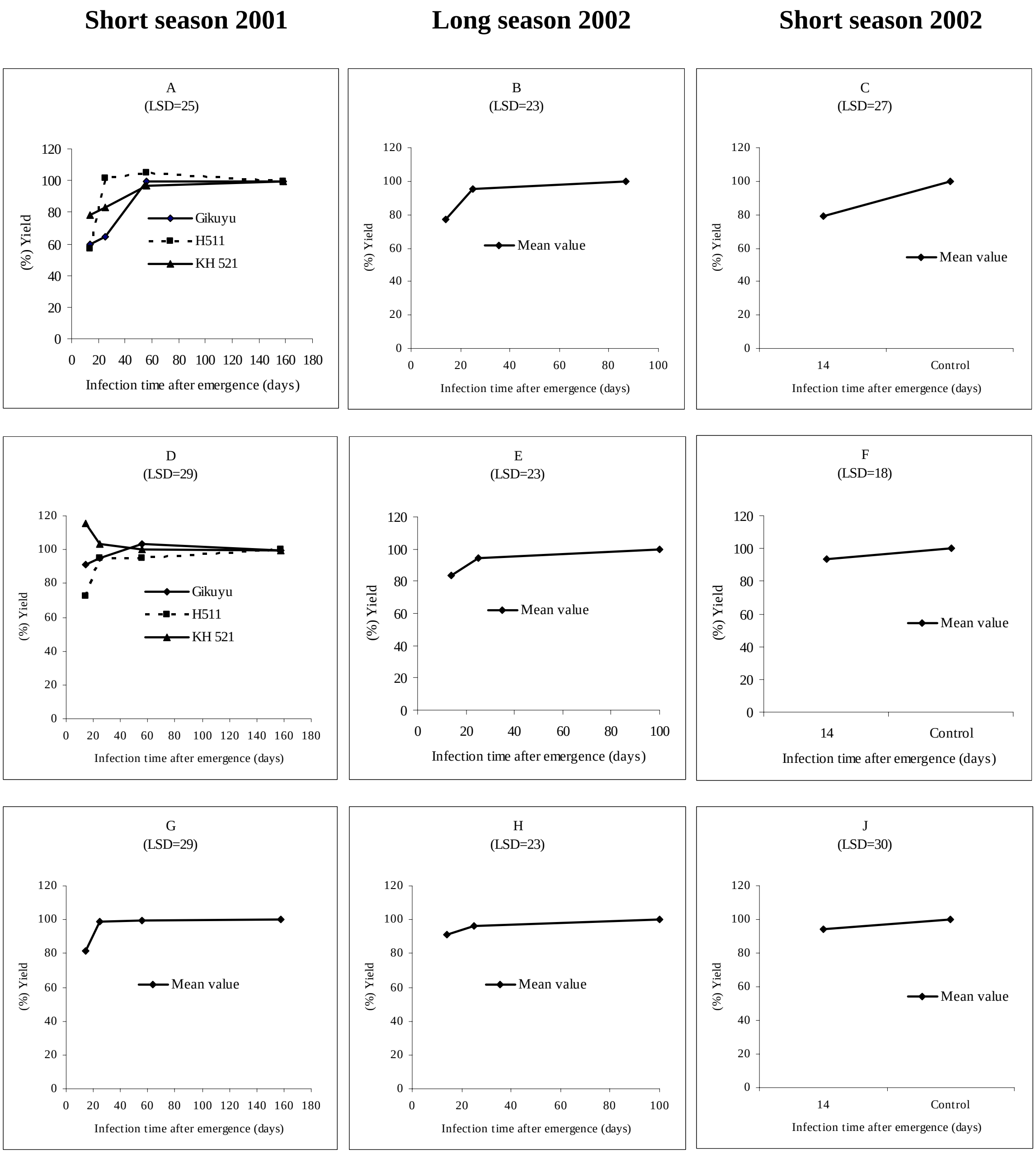


Figure 12 – As Fig. 11 except that yields are expressed relative to the uninfected control yield, which is always shown as 100%. Cultivars are shown separately where there is evidence of a difference in response to time of infection between cultivars. Note that yields of treatments exceed 100% if the actual yield is greater than the uninfected control. (A-C: thinnings; D-F: stover; G-J: grain)



The effect of cultivar

The ability of resistant cultivars to alleviate the impacts of early infection was clearly demonstrated with respect to both forage and grain yields. In the short season 2001, as expected, KH 521 was the cultivar least affected by MSV, with some evidence for a smaller effect on forage and grain yields of early infection by MSV compared to H511. Although the tolerant cultivar (KH 521) yielded more forage and grain than other cultivars, it should be noted that it is a later maturing cultivar. Its greater crop duration clearly led to a higher yield in all treatments since irrigation was carried out during most of the first season's trial. Calculating yields relative to the control compensates for these cultivar effects and in the 2001 short rains season, KH 521 had a thinning yield loss of 24% with early infection by MSVD compared to 43% recorded by H511 while Gikuyu had a yield loss of 40% (Fig. 12 A). In the 2002 long rains, the mean yield loss due to MSVD with early infection of 33%. In the 2001 short rains season, KH 521 did not record any yield loss of stover yield with early infection while H511 and Gikuyu had yield losses of 24 and 9% respectively. The mean grain yield losses for all varieties were 28 and 9% in the 2001 short rains and 2002 long rains seasons, respectively (Fig. 12 A – J). Interestingly, the local landrace (Gikuyu) seemed tolerant of MSVD with respect to grain yield. In the long rains season 2002, there were significant differences ($p<0.05$) in thinning; stover and grain yield between cultivars. As expected the susceptible variety H614 suffered the highest reduction in thinning yield at 14 days of infection while the resistant KH 521 suffered the least. On the other hand, H614 yielded the highest amount of stover followed by KH 521. H614 is suited to the high and medium altitudes and usually grown in the long rain season. With respect to grain yield, Gikuyu seemed to suffer most reduction especially at 14 days. It should be noted that in the 2002 long rains, there were insufficient leafhoppers and as a result, inoculation percentages were low. The low MSV impact could have led to compensatory growth by uninfected plants and hence lack of significant interaction between time of infection and cultivars. Evidence to support this hypothesis was found by analysing mean yields of thinnings *per plant* rather than *per unit area*. It is then clear that the yields of thinned plants did not differ significantly whether the plants were infected 14 or 35 days after emergence or not at all (Fig. 13). By contrast, the susceptible H614 showed a large reduction in the mean thinning weight per plant when infected 4 days after emergence compared to later or nil infection (Fig. 13).

In the 2002 short season 2002, the resistant cultivar PAN 67 significantly yielded higher thinnings ($P<0.001$) and stover ($P<0.05$) than the susceptible cultivar H511. Cultivars differed in total percentage leaf area infected which changed with plant age. H614 had the highest leaf infected (20-40%), followed by Gikuyu (5-17%). KH 521 had the lowest percentage infection ranging from 2 to 7% (Fig. 14).

Figure 13: Effect of time of infection by MSVD on mean weight *per thinned plant* as a measure of impact of disease on three different maize cultivars in the 2002 long rains season

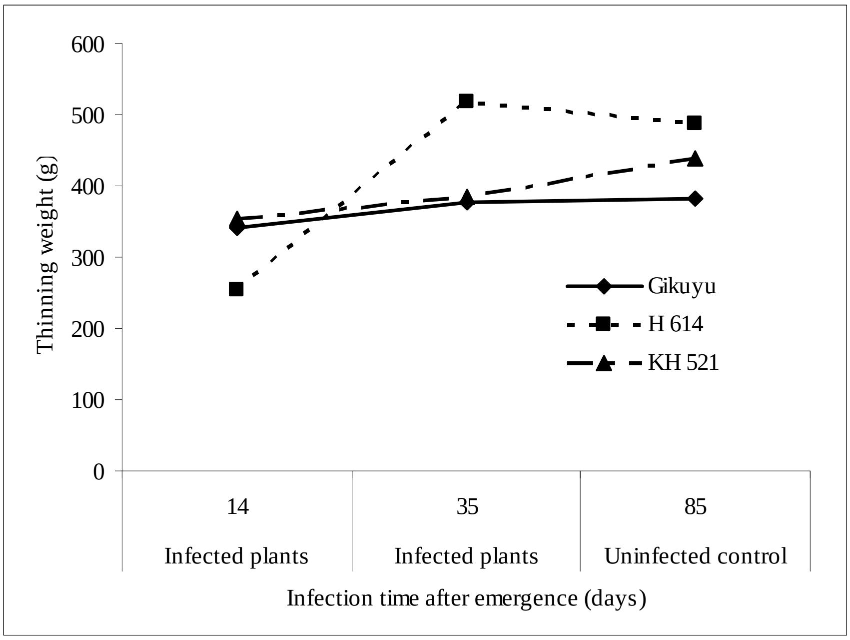
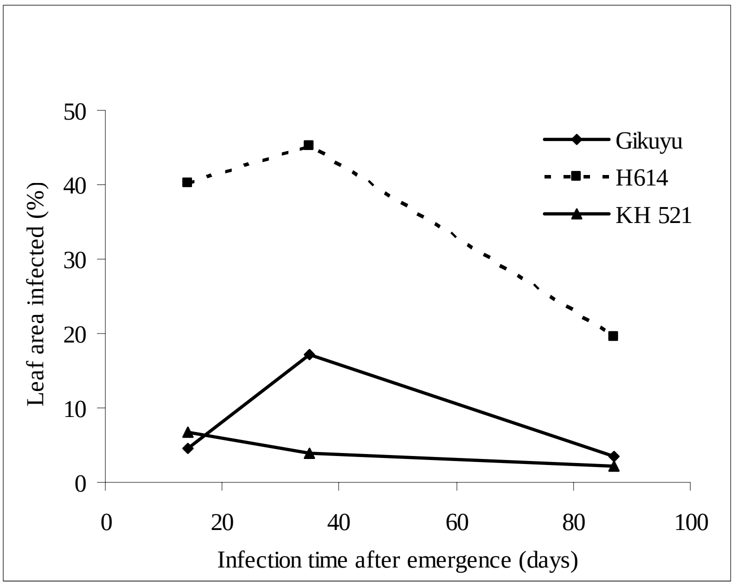


Figure 14: Percentage of crop leaf area infected by MSVD at thinning in the 2002 long rains.



4.3.3 Effects of infection with *maize streak virus* on the quality of maize forage

Forage quality was examined at the physical level by leaf:stem ratio, chemically to determine crude protein (CP), neutral (NDF) and acid (ADF) detergent fibre content, dry matter digestibility and also biologically using the *in vitro* Reading Pressure Technique. Leaves, stems and, for thinnings only - any cobs, were analysed separately for in both stover and thinnings. The main objective was to determine whether MSVD altered forage quality and so even for 100% artificially infected treatments, plants where the attempted inoculation had failed were excluded from the analysis. Likewise, for the uninfected controls, plants which had become infected naturally, were also excluded. The analysis which follows for the 2001 short rains (from Lukuyu *et al.* 2004) is indicative of results obtained for the effect of MSVD. The analysis was repeated for the 2002 short rains samples to assess the likelihood of there being seasonal effects on quality.

Early infection with MSVD (14 days post-emergence) improved forage quality by increasing crude protein concentration ($P<0.01$) from 93 g/kg (control) to 112 g/kg in thinnings and from 44 g/kg (control) to 52 g/kg in stover when infection occurred 14 days post emergence (Table 4 A, B). Conversely, NDF increased ($P<0.01$) from 487 g/kg to 507 g/kg (control) in thinnings and from 677 g/kg to 705 g/kg (control) in stover with delay in time of infection. Across time of infection (from 140d) with MSVD, CP decreased linearly ($P<0.01$) as NDF concentration of maize thinnings increased. A similar trend was observed for maize stover. Perhaps because of its resistance to MSVD, the cultivar, KH 521, had the least CP concentration in both thinnings and stover and the highest NDF content in thinnings.

This apparently lower quality of “early (14 d) infected” forage from KH 521 was, however, probably due to its higher yield since its total yield of protein was also greater than for the other two cultivars. Fertiliser level did not affect CP or NDF in either thinnings or stover. Generally, although CP is highest with the earlier infections, the gross offtake of protein is low because of low DM offtake, due to stunted plants as a result of early infection.

All cultivars showed a negative linear relationship of thinning yield to CP % over the range of 6 to 14% (Fig. 15; Gikuyu r^2 =0.0743; H511 r^2 =0.559; KH521 r^2 =0.0113.). Higher DM yields resulted in lower CP content of thinnings; an effect which was most pronounced in H511 and least in KH521. Conversely, all cultivars showed a positive linear correlation (Gikuyu r^2 =0.1098; H511 r^2 =0.0584; KH521 r^2 =0.1322.) of thinning offtake to NDF % over the range of 41 to 57%. Higher DM offtake resulted in higher %NDF of thinnings; more pronounced in KH521 and least in H 511. Only for the susceptible H 511 was there a significant relationship between CP concentration and DM offtake.

The relationship between stover offtake to CP and NDF % is shown in Figures 2 and 3. Similary, all cultivars showed a negative linear relationship (Gikuyu r^2 =0.082; H511 r^2 =0.0038; KH521 r^2 =0.0081.) of stover offtake to CP % over the range of 2.8 to 8.3 %. On the other hand, there was a positive linear correlation (Gikuyu r^2 =0.1581; H511 r^2 =0.0502; KH521 r^2 =0.0463.) of stover offtake to NDF % over the range of 58 to 75%. However, differences in relationship between offtake to CP and NDF are less conclusive for stover. This might be because by harvest time there was compensation in growth since the weak, stunted plants were removed during thinning. The criterion used during thinning was to remove the weakest stunted plants, as is the farmer practice.

Table 4: Main effect means on the effect of infection with *maize streak virus*, cultivar and fertiliser level on the yield (t/ha DM) and chemical composition (g/kg DM) of A) thinnings and B) stover for three maize cultivars grown at KARI-NARC-Muguga in the 2001 short rains season. For fertiliser treatments and other agronomic aspects, see Appendix 2a, 2001 short rains. For methods of chemical analyses, see Lukuyu *et al.* (2004)

A	MSV (days after germination)			Cultivar				Fertiliser level		s.e.d.			
Parameter	14	36	56	Control	Gikuyu	H 511	KH 521	Low	High	MSV	Cultivar	Fertil-iser level	Inter-action
Yield (t/ha DM) of thinnings	3.0	3.9	4.7	4.6	3.4	4.1	4.7	4.07	4.01	0.30***	0.26***	0.52	0.82*
Dry Matter	928.3	928.9	930.6	927.8	941.2	912.8	933.2	930.2	927.6	3.96	3.43*	2.80	11.44
Crude protein	112.3	92.6	88.5	93.4	113.5	100.5	74.8	96.0	97.7	5.53**	4.79**	3.91	15.99*
Acid Detergent Fibre	278.2	279.0	278.4	286.1	273.0	271.6	298.0	280.7	280.2	5.28	4.58**	3.73	15.49
Neutral Detergent Fibre	486.9	492.7	496.7	506.8	472.1	476.1	542.6	495.4	496.0	12.12	10.51	8.57	35.86
Ash	83.5	87.7	78.5	77.0	83.3	82.5	79.3	81.3	82.3	3.89*	3.37*	2.75	10.33**

B	MSV (days after germination)			Cultivar				Fertiliser level		s.e.d.			
Parameter	14	36	56	Control	Gikuyu	H 511	KH 521	Low	High	MSV	Cultivar	Fert-iliser level	Inter-action
Yield (t/ha DM) of stover	6.3	7.6	6.9	7.0	6.3	6.9	7.6	6.6	7.2	0.54	0.47**	0.93**	1.22
Dry Matter	932.3	930.9	931.7	931.3	929.6	932.2	932.9	931.3	931.9	1.61	1.39*	1.14	4.44*
Crude protein	52.3	40.7	48.1	44.4	53.5	43.5	42.2	45.0	47.7	3.20**	2.78**	2.27	9.18
Acid Detergent Fibre	383.1	395.3	391.5	405.0	386.5	407.9	385.6	395.7	391.6	8.58	7.43	6.07*	24.55
Neutral Detergent Fibre	677.4	685.2	681.8	705.1	674.6	703.3	683.7	688.6	686.1	11.28	9.77*	7.98	32.11
Ash	79.5	78.8	77.5	78.5	76.4	81.4	77.9	78.8	78.8	3.28	2.84	2.32	9.58

*P<0.05; **P<0.01

Figure 15: Relationship between cultivar offtakes (t/ha DM) and crude protein content (%) of maize thinnings. Regression equations for cultivars were: Gikuyu, Y = - .1824x + 5.5197; R2 = .0743. Hybrid 511, Y = -.4955x + 9.0371; R2 = .559. Muguga 1, Y = -.0785x + 5.2359; R2 = .0113. From Lukuyu et al. (2004)

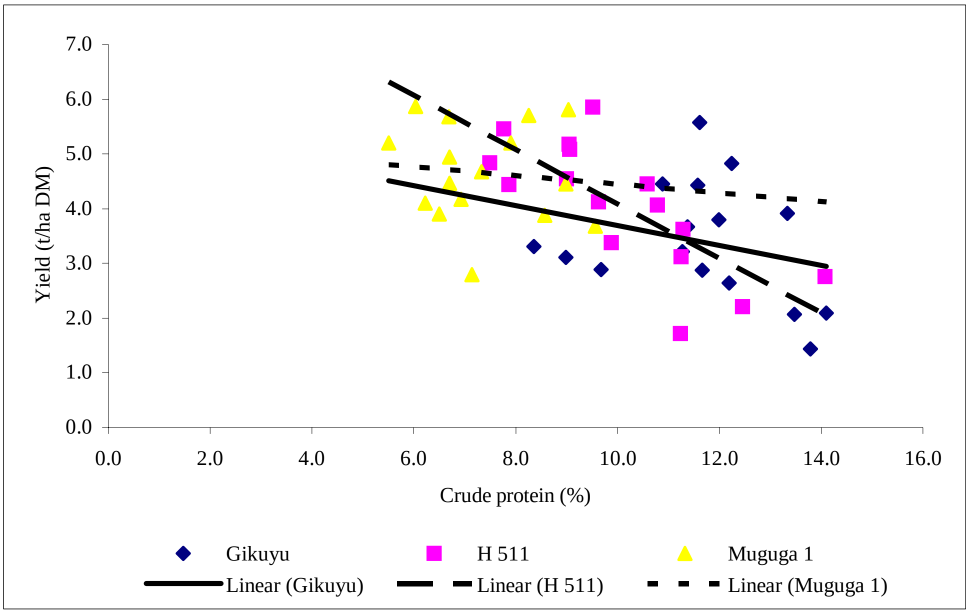
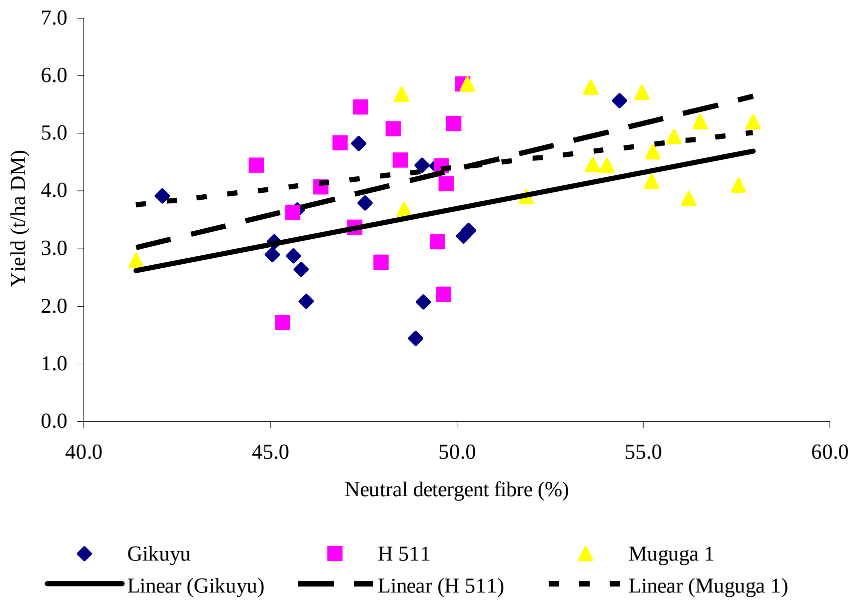


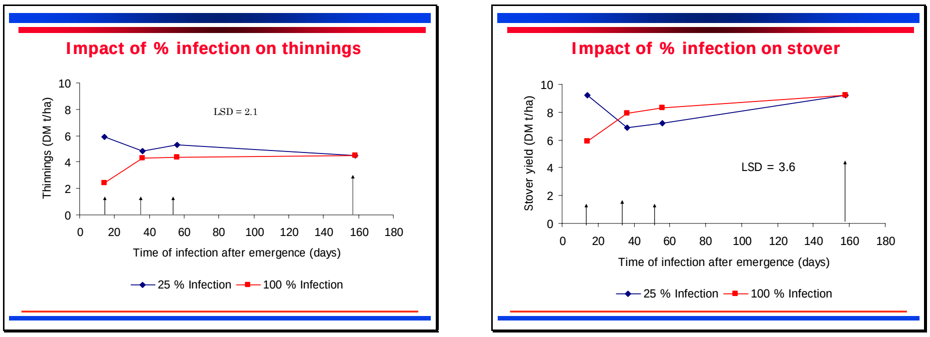
Figure 16: Relationship between offtake (t/ha DM) of cultivars and neutral detergent fibre content (%) of maize thinnings. Regression equations for cultivars were: Gikuyu, Y = - .1255x – 2.581; R2 = .1098. Hybrid 511, Y = -.1587x - 3.5548; R2 = .0584. Muguga 1, Y = -.0755x - 0.6395; R2 = .1322. From Lukuyu et al. (2004)



4.3.4 The effect of degree of infection and date of planting on maize forage

The issue arose from previous research that early natural infections of MSVD do not have the same impact on grain yields as early artificial infections. The hypothesis was tested that this discrepancy may be due in part to the plasticity of the cereal plant such that if one plant is stunted due to MSVD, adjacent uninfected plants may "expand" to fill the space. Experiments were therefore conducted to test this hypothesis by showing that where partial (25%) artificial inoculation takes place, yields are not depressed by MSVD to the same extent as when 100% inoculation occurs. The results obtained (shown below for forage offtake) confirmed this hypothesis (Fig. 17)

Figure 17. The effect of inoculating either 25% or 100% of plants of the susceptible maize cultivar H511 with MSVD on yield of thinnings and stover in the 2001 short rains.



Another or additional explanation for the discrepancy could relate to the date of infection – from results already discussed, a late natural infection would not be expected to have the same impact as an early one; and one major difference between natural and artificial infection is that the disease takes time to spread through a field. An attempt was made to study this effect of time of infection in the natural environment by varying the planting dates of maize crops of susceptible (H614) and resistant (PAN67) cultivars (Appendix 2b). This experiment was carried out three times, twice at FTC Waruhiu and once on-farm at Githunguri. Only in the latter case were natural MSVD infection levels high enough for analysis of the results and even then only attained about 36%.

Table 5. Natural incidences of MSVD on two maize cultivars planted on three dates in a randomised block small plot experiment carried out on a farmer's field at Githunguri, 2003 long rains. The earliest date was at onset of the rains.

		Planting dates			
	Cultivar	31 Mar 2003	7 April 2003	14 April 2003	s.e.d
MSVD incidences (%)	H 614	26.00	31.60	31.40	8.88^{ns}
	PAN 67	7.00	10.10	10.70	

Field observations showed that crops from all the three planting dates were free from MSVD, before the three-leaf stage. Incidences of MSVD infection appeared as early as the four-leaf stage on PAN 67. Crops from all the planting dates were infected at the fifth leaf stage. Cultivar significantly ($p<0.001$) influenced the leaf stage at infection. Though not significantly, disease incidences showed some tendency to increase with delay in planting dates with the last planting showing the highest infections (mean=21.1%) and the first, the lowest (mean=16.5%) (cf. Table 5). The MSVD incidences were highly significantly influenced by cultivar ($p<0.001$). The H 614 recorded a mean % infection of 29.7 (range 26 – 31%) compared to a mean of 9.3 (range 7 – 11%) of PAN 67 (Table 5).

4.3.5 Participatory evaluation of the MSVD resistant and susceptible cultivars exposed to natural infection (Output 1 and 4).

The main reason for this evaluation was to answer the question: Are the forage and grain characteristics of maize resistant to MSVD acceptable to the farmers. When farmers were compared uninfected with artificially infected resistant and susceptible cultivars at farmer field days, they would almost always prefer the resistant cultivar, but we had not provided any opportunity for farmers to evaluate the resistant cultivars in the naturally infected trials such as thant described in 4.3.4. This was carried out in August 2003 at Githunguri (Appendix 5a). An additional evaluation of taste only was conducted separately with the Kamari womens' group in October 2003 (Appendix 5b).

The scoring results for the first evaluation (Appendix 5A) showed that farmers had almost the same preference for the two varieties, PAN 67 and H614. However each variety has its own strong preferred attributes. PAN 67 was preferred for early maturity and absence of disease while H614 for its big cob and stalk (more fodder).

Farmers were probed about changes that they might adopt after seeing and discussing about the trials.

1. They would plant early and at the same time for all their patches on their farms and varieties. This is because a part from what they have observed from their own farms that early planting guarantees yields especially in season with insufficient rainfall. The trials also showed that early planting may reduce incidences of MSVD and therefore they might get higher yields. Asked what determines their time of planting. They said it is normally determine by

- Usually onset of rains
- Availability of seed in the local stores and money to pay for it

2. Farmers said they would introduce PAN 67 as an *additional* variety to H614 but plant them on different patches. This is because MSVD occurs intermittently (i.e. does not always occur in all seasons). So that in the event of MSVD they will be assured of a grain harvest from PAN 67 and rely on H614 for fodder. In case is there is no MSVD in the season, then they will take advantage of the best attributes of both varieties (some sort of risk aversion). Asked how they would take advantage of the attributes, they qualified that while PAN 67 would mature early and provide

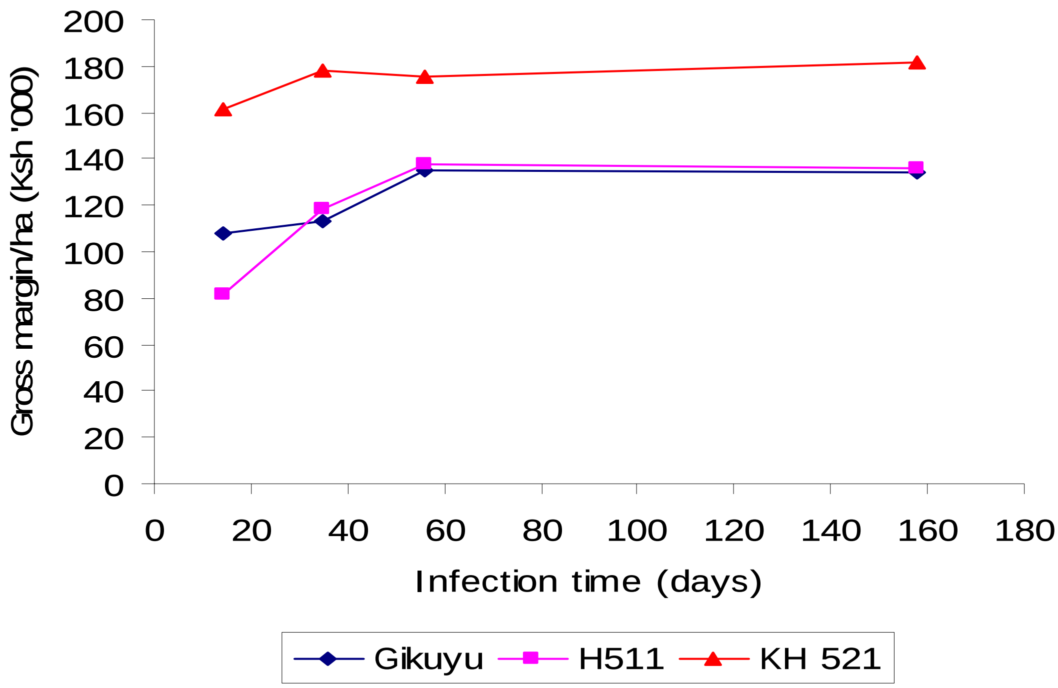
green maize for food and fodder for livestock early in the season, H614 is good and preferred for roasting and has ready market in all urban areas. It also prepares sweet local dishes like 'githeri' and 'ugali'.

The Kamari group in October 2003 compared flavours and size of PAN67 and H511 and clearly preferred the flavour of PAN67 (Appendix 5b).

4.3.6 Economic evaluation of MSVD resistant cultivars (Output 3)

A simple evaluation of the values of forage and grain outputs less input costs was carried out indicating a much higher gross margin for KH521 compared to the other cultivars and some evidence that the effect of the disease was lower relatively in the resistant cultivar KH521.

Figure 18 Gross margins of the three cultivars infected with MSVD at various periods post-crop emergence in the short rains 2001. The uninfected control is shown as though it were infected on the date of harvesting at the end of the experiment. (Based on yield data in Fig. 11 A, D, G).



4.4 Weeding regimes research (Outputs 1 and 3)

The research on weeding regimes comprised a series of field experiments described in section 3.3/4. Results were presented at the Stakeholder meeting by Dr Jedidah Maina (See presentation by Dr Maina in Murdoch et al., 2004) and again by Dr Murdoch at the International Weed Science Congress in Durban, June 2004. The main scientific content of this research comprised an MSc project carried out at KARI-NARC-Muguga. The MSc thesis was submitted around May 2003 and the final defence took place in July 2004. A copy will be lodged with the project's sponsors when available from the University of Nairobi.

The impact of weeds on maize forage yield and quality (Output 1)

Farmers perceived that couch grass (*Digitaria*) and sedges (*Cyperus*) had the greatest impact on yield of stover and grain (Figs 19, 20; McLeod *et al.* 2001).

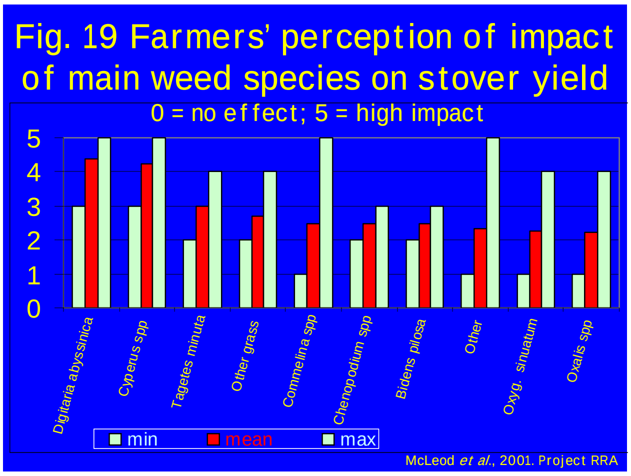


Fig. 19 Farmers' perception of impact of main weed species on stover yield

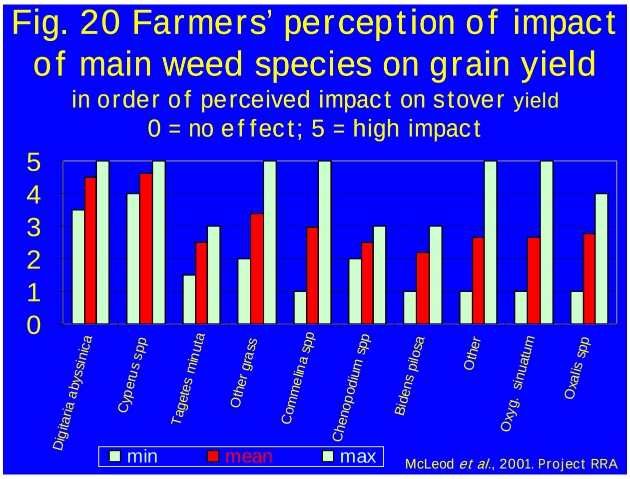


Fig. 20 Farmers' perception of impact of main weed species on grain yield

The longitudinal study confirmed that many farmers weeded late.

In comparison to the recommended time of first weeding - 2-3 weeks after planting (WAP), the farmers in the longitudinal survey...

- Short rains 2001: mostly 3-4 WAP
- Long rains 2002: mostly 3-4 WAP
- No first weeding in three patches in each season

Total 31 patches (short 2001); 47 patches (long 2002)

- Flowering weeds at first weeding occurred as follows:
- Short rains 2001: 7/31 patches
- Long rains 2002: 17/47 patches

Main species Commelina and Galinsoga

The second weeding, recommended 6-8 weeks after planting, was only achieved in 4 and 6 patches out of 15 and 47 in the short and long rains, respectively.

Time of second weeding (weeks after planting)	Short 2001 Number of patches	Long 2002
Up to 8 weeks	4	6
9-21 weeks	2	6

Handpulling for forage	9	34
Partial weeding	0	1
Not available	14	0

In the majority of cases, handpulling for forage was the only second weeding. It is therefore of interest to know if many weeds were flowering at the time of the second weeding. Data is not available for all patches but the following shows that large numbers of patches contained flowering weeds

Short rains 2001: 20/26 patches

Long rains 2002: 18/30 patches

The main species flowering in more than 7 patches in both seasons were *Bidens pilosa*, *Commelina* spp., *Tagetes minuta*, *Galinsoga parviflora* and *Amaranthus.*

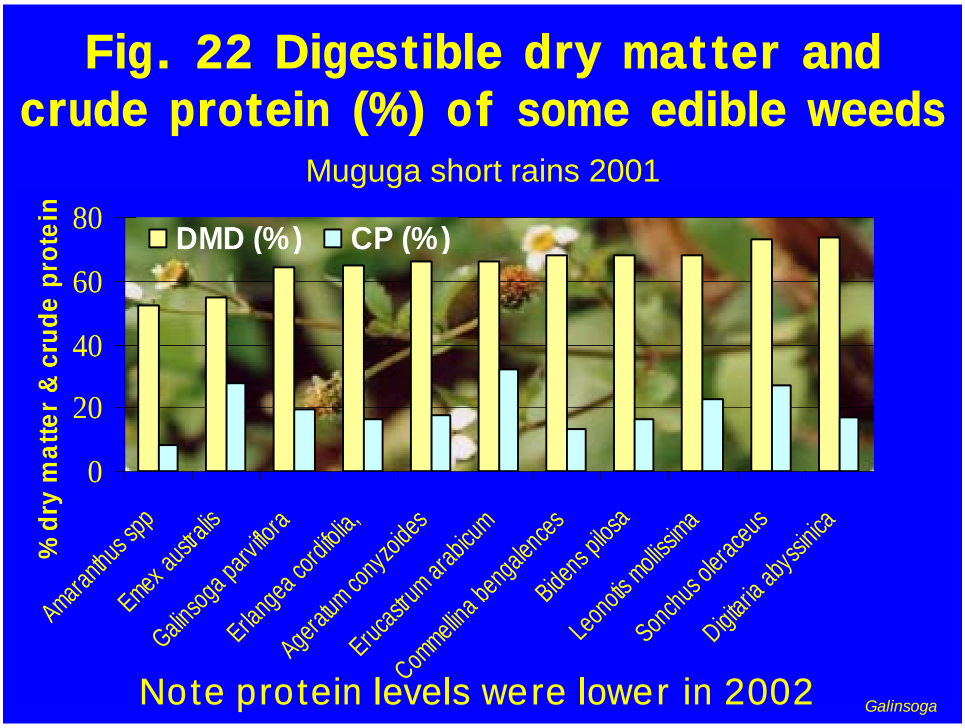
The general result from the weeding regimes trials in terms of yields of forage and grain were that there was ***no*** significnant difference in yield between the various weeding regime treatments tested, provided the weeds were controlled (Maina in Murdoch *et al.* 2004). Uncontrolled weeds by contrast had a serious dual effect: they reduced yield in the season they grew and increased weeding time in the subsequent season.

The bottom line as far as weed control using herbicides is concerned was to confirm earlier results of highly positive benefits of using herbicides in some seasons but by no means in all. The most profitable for use of herbicides was the shot rains 2001 where the marginal benefit of using herbicides compared to other regimes was 10000 KSh/ha. However this was not repeatable and in some cases where labour is costed at a lower rate, handweeding was more profitable (figures in red below, Fig. 20).

Fig. 21 Reduction (-) or increase (+) in control costs using herbicides
{Herbicide treated – hand weeded twice} in KSh/ha

	Hand-weed	@ Ksh/d	Short 2001	Long 2002	Short 2002	Long 2003
Muguga	**2 & 8 weeks**	**180**	**-10000**	**-6620**	…	…
FTC Waruhiu	**3 & 8 weeks**	120	…	…	-2600	-900
	3 & pull	120	…	…	-1910	**+2540**
Kamburu (on farm)	**3 & 8 weeks**	100	…	…	**+420**	**+1100**
	3 & pull	100	…	…	-560	**+2540**

With respect to the use of weeds themselves, those which are edible were nutritious (Fig. 22) in terms of protein content and digestible dry matter although less so in 2002 than in 2001..



Uncontrolled weeds, however, did have a detrimental effect on maize forage quality (Fig. 23) and digestible dry matter (Fig. 24)

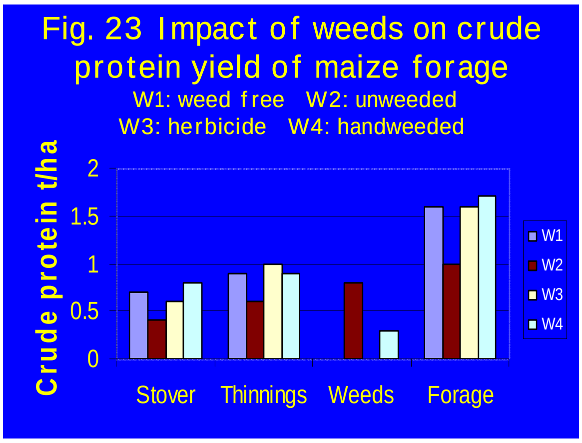


Fig. 23 Impact of weeds on crude protein yield of maize forage

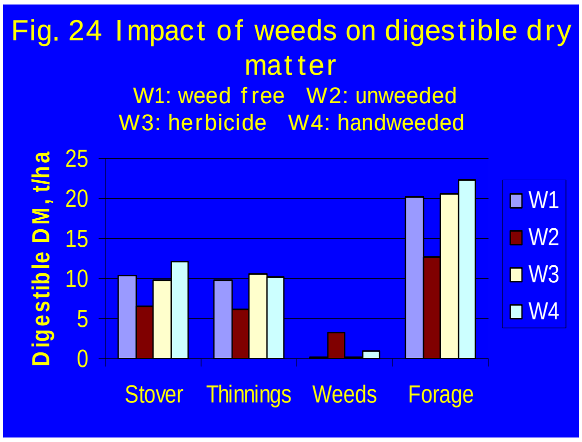


Fig. 24 Impact of weeds on digestible dry matter

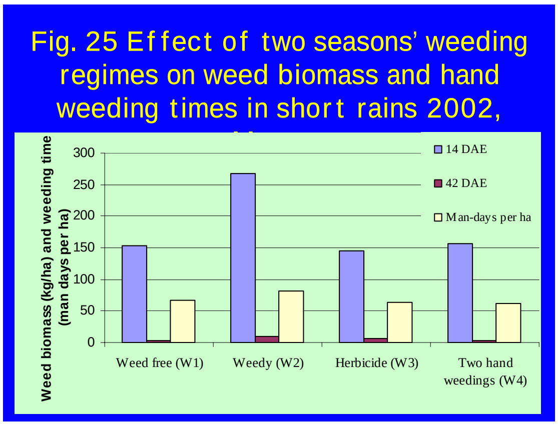


Fig. 25 Effect of two seasons' weeding regimes on weed biomass and hand weeding times in short rains 2002,

Uncontrolled weeds, therefore, in weeding regime 2 reduce forage quantity and quality, but they also have the consequence in subsequent crops of increasing the time which must be spent hand-weeding (Fig. 25 – the man-days per hectare are significantly higher for weeding the weedy regime (after two seasons of uncontrolled weeds).

4.5 Output 2: Survival of spores of maize head smut and seeds of weeds after passage through cattle and composting

A detailed report of this was presented at the Stakeholder workshop (Murdoch, Njuguna and Owen, 2004) and details of the survival of head smut spores by Njuguna, Njoroge and Jama (2003). Some *Amaranthus* seeds survived and could therefore be disseminated, but the numbers were small (Table 6). No other weed species survived (data not shown). Spores survived passage through the animal but not the combination of the latter followed by composting for three months (Table 6).

Table 6. Transmission of *S. reilianum* spores and *Amaranthus* seed through manure. Spores survival was detected by development of head smut on plants of a susceptible maize genotype . Seed survival was evidenced by emergence of seedlings over at least six months.

Treatment	%maize plants smutted	Number of germinated seeds of *Amaranthus* spp.
Fresh cow dung (T1)	43	3.75
Dried cow dung(T2)	14	37.25
Composted cow dung(T3)	0	9.75
Positive control (T4)	53	438
Negative control (T5)	0	1.5

The most important messages for farmers are as follows:

- Although some weeds are good forage for dairy animals, do not feed seeding weeds to livestock.
- Plant maize cultivars that are resistant to head smut if the disease occurs frequently.
- Do not feed smutted maize forage to cattle, but if you do, then compost cow dung for at least three months before use.
- If you buy manure from afar look out for new weeds.

4.6 Output 1: Push-pull and forage conservation studies

Two detailed reports of this were presented at the Stakeholder workshop by Sam Njihia and David Miano Mwangi. (Murdoch, Njuguna and Owen, 2004)

The Kamari womens' group set up comparative trials at Waruhui Farmer Training Centre and the Karweti farmers' group on one of their own holdings. Establishing *Desmodium* proved unreliable by seed and transplanting of vines was found more appropriate on the sloping fields of Kiambu. A major challenge was adaptation of the system to the rotations practised in Kiambu.

Table 7. Percentage of plants affected by stem borers in each plot of push-pull trial, short rains 2003. (Numbers and total sample in brackets).

	Kamari push/pull	Kamari control	Karweti push/pull	Karweti control
H511	0.72 (17/2352)	3.79 (91/2400)	4.71 (49/1040)	9.4 (116/1232)
PAN67	0.64 (15/2352)	3.25 (78/2400)	7.02 (73/1040)	8.4 (74/880)

Preliminary observations suggest that at both Kamari and Karweti the push- pull plots have less incidence of attack than the controls (Table 7). While these results may (hopefully) be attributable to push pull effect, there is need for proper validation studies since the results are based on one season's data and there were various differences in, for example, soil fertility between the control and push-pull plots

Economically, the labour costs of setting up the push pull plots were very high, but as predicted the financial benefits were improving as the trial progressed into the second season. Combining the system with forage conservation of the forage produced during the wet seasons and costing the value and milk output of that conserved forage, if used in the dry season, showed a very large increase in output, which is likely to lead to considerable alleviation of poverty and improvements in livelihoods of those adopting the system. The detailed account of these calculations is not presented here but may be found in the stakeholder meeting report (Murdoch, Njuguna and Owen, 2004).

4.7 Output 4: Extensionists and farmers trained to promote sustainable maize-dairying, including how integrated pest management may affect the availability of forage.

4.7.1 Introduction

Output 4 was achieved in a variety of ways as indicated in the dissemination strategy (Table 8). The main activities were the farmer field day, extension field day and the final workshop. However, the participatory nature of much of the research ensured that throughout the project farmers (and often extension) were directly involved in the research and in an ongoing process of sharing and exchanging information and experience.

Table 8 Dissemination strategy for R7955 (RPLK=resource poor livestock keeper; IPM=integrated pest management where 'pests' comprise weeds, pests and diseases and in Central Kenyan Highlands most intractable problems identified by small-scale dairy farmers were maize streak virus disease (MSVD) maize stalkborer and weeds).

Audience	Objective(s)	Message	Medium
A. Promotion partners			
Extension (location specific)	That they should promote technology (project outputs)	Better IPM (weeds, pests, diseases) → more maize → more forage (and grain) → less seasonal forage shortages (esp. if combined with small polythene bag silage technology) → more milk → more money → improved livelihoods of RPLKs	Stakeholder workshop; active participation in research; project leaflet; technical reports; involving them in preparation of dissemination materials (e.g. leaflet).
NGOs	-Ditto-	-Ditto-	-Ditto-
B. Beneficiaries			
KEPHIS	Raise awareness	In cultivar selection, forage is important	Stakeholder meeting; lobbying; letter
ARIS	Specific action	Get Muguga-1 on to seed market as Kiambu farmers want it	-Ditto-
Farmers (location specific) mostly RPLKs but also some producing forage for same.	Raise awareness; pass on knowledge; promote action	Essentially as Extension, but more concisely - more milk → more money.	More widely after project ends via service providers (NGOs, extension). Locally with farmers when project is live: Participation in research; field days; farmer exchange visits to demonstrate technology; extension leaflet; perhaps some radio.

4.7.2 Extension staff training day (27th January 2004)

Demonstrations and extension staff feedback

An extension staff training day was held in Waruhiu Farmers Training Center-Githunguri in January 2004. 22 staff attended from all six divisions in Kiambu District: Kikuyu; Kiamba; Githunguri; Limuru; Lari; Ndeiya. An internal report on the workshop was produced (Njuguna, Dorward and Murdoch, 2004).

Five technologies were demonstrated during the field day:

- The push-pull system to control stem borers in maize
- The use of MSV resistant maize cultivars
- Weeding regimes – particularly the use of herbicides to control weeds in maize
- Control of head smut diseases in maize and napier grass
- Feed conservation by ensiling

For each of these there was a demonstration plot (a physical demonstration for feed conservation) which staff visited and discussed with research staff.

The extension staff were asked to rank technologies in order of suitability for their own division (Table 9).

Table 9 Ranking of technologies' suitability for implementation in each division

Ranked	Push–pull	Maize cultivars resistant to MSV	Control of head smut of maize and Napier grass	Weed control	Forage conservation
1st	2	1	2		1
2nd	1	4			1
3rd	1	1	3		1
4th	1		1	2	2
5th	1			4	1

MSVD resistant cultivars were ranked 1st or 2nd by the most divisions, followed in order by 'push-pull', control of head smut and forage conservation. Weed control was ranked 4th or 5th by all divisions.

Staff from each division were also asked to develop a plan for implementation of the technology they ranked first. Details are given in Njuguna, Dorward and Murdoch (2004).

Overall the extension Divisions expressed that they are keen to implement the above. However they reported that they have insufficient information on the technologies and requested further support in the form of training and ongoing contact with research staff. Transport was also identified as a constraint.

4.7.3 Farmers' Field Day (28th January 2004)

A farmers' field day was held in Waruhiu Farmers Training Center- Githunguri in January 2004. The main objective was to provide information to farmers in Kiambu District on each of the technologies being promoted by the project.

In total 208 people participated in the field day of whom 185 were farmers (104 female, 81 male). The farmers were drawn from all the six divisions of Kiambu district ; Githunguri, Ndeiya, Kiambaa, Kikuyu, Lari and Limuru. In addition representatives from the Kenya Institute Of Organic Farming (KIOF) and Land O Lakes NGOs attended. Each of the five technologies (push-pull for maize stalk borer control, maize cultivars resistant to maize streak virus disease, weeding regimes, control of head smut of maize and Napier, grass and forage conservation) were introduced via demonstrations and discussed.

Farmers visited each demonstration in groups where the technology was explained and discussed. In order to assess their potential uptake each farmer was asked to complete a questionnaire towards the end of the day. 131 (70.8%) farmers responded. Full results from the questionnaires are given in Mbure, Musembi and Njuguna (2004) and a brief summary is presented here.

97.7 % of the respondents reported that they were interested in trying 'push-pull' on their farms. The most frequently reasons given were that 'push-pull' would help in the control of stem borers and that it would increase the yield of fodder and grain. 91.6% of respondents said they would plant one or more of the demonstrated maize varieties. Varieties preferred by farmers were KH521 (Muguga1), PAN67 and Pioneer 3253. PAN67 was preferred because of its sweet taste, high yields of fodder and grain, resistance to MSVD and the stay green effect of the stover. KH521 was preferred for its high yields of fodder and also grain and resistance to MSVD. Pioneer 3253 was particularly liked because it is resistant to head smut.

82.2% of the respondents said they would like to try herbicides to control weeds in maize. The main reasons given were that they had seen that herbicide application saves on labour, and herbicides are more effective and cost effective than hand weeding in controlling weeds. 66.7% of the respondents had napier head smut on their farms. All the respondents preferred Kakamega 1 variety mainly because of its resistance to head smut disease. Farmers also reported that the variety grows fast and is less hairy than the local varieties. 81.0% of the respondents reported that they had maize head smut on their farms. The most preferred maize varieties in all the divisions were PAN67, Muguga1 (KH521) and Pioneer 3253.

96% of farmers reported that they believed that if they implemented the technologies they would have some surplus forage at some time in the year and 89% of farmers stated that they would choose the tube silage method as a means of conservation.

Representatives from two seed companies (Freshco Seeds and PANNAR) were present at the field day. 20 2kg samples of KH521 seed were distributed to farmers groups for members to try on their own land. In addition 25 2kg packets of KH521 were sold by the representatives. Seed is also now available from local seed suppliers.

4.7.4 Farmer field day February 2002, KARI-NARC-Muguga.

The field day was attended by 101 persons mostly farmers (61), a number of agricultural extension officers (6), research scientists, Non-Governmental Organisation (NGO) officers and seed company representatives.

Farmers were taken round demonstrations on:

- Maize streak virus and the use of new resistant varieties eg Muguga 1 PAN67.
- The use of herbicides for the control of weeds.
- Silage making.

Feedback was collected through a questionnaire issued to the farmers and the comments and the questions they asked. Overall farmers were extremely interested in the demonstrations and a range of issues were raised in discussion. Details of these are given in Musembi (2002). All the farmers reported that they would be interested in future field days and would like to be involved through having some of the trials conducted in their own fields other than at the centre.

4.7.5 Visit by a group of farmers from Githunguri Division to Vihiga District on the push-pull technology. 6th –8th November 2002.

Twelve farmers from 12 CBOs based in Githunguri Division, Kiambu district, 5 project scientists from Kenya Agricultural Research Institute (KARI), one Extension officer for Githunguri and one officer for Kenya Institute of Organic Farming (KIOF) visited Vihiga in western Kenya to see and discuss the 'push-pull' system. The group visited three separate farms who had implemented the system to control stem borer and *Striga* and to increase forage production. At each farm farmers had been working with ICIPE to establish push-pull plots. The hosts spoke enthusiastically about the system and the visiting farmers were clearly impressed and were keen to establish their own plots in Githunguri. The visit was an important step in working with farmers to establish on-farm demonstration plots of 'push-pull' in Kiambu.

4.7.6 Visit by Kamari and Karweti farmers groups to Kamburu. 13th August 2003.

Kamari and Karweti farmers groups visited Kamburu to view the effects of MSV infestation, which was more pronounced in Kamburu. MSV and its effects were discussed and farmers observed the resistance of PAN 67 to MSV as compared to H511. They also were shown the weeding trials.

4.7.7 Kamburu Exchange Visit to Kamari to view the Push Pull System. 4th July 2003.

Kamburu women group visited Waruhiu FTC to view the Push-Pull work.

20 members (eleven women and nine men), two extension officers, the Divisional Agriculture and Livestock Extension Co-ordinator and 5 research staff were present.

Farmers' problems with stem borer and the principle of push-pull technology were explored with farmers using photographs and writing on the blackboard. Farmers confirmed that stem borers are a problem and reported that they apply soil, tobacco or ash but not chemicals.

None of the farmers had heard about the push-pull technology before about *Desmodium*. Having seen the push-pull plot farmers expressed interest in it and one farmer requested *Desmodium* vines.

4.7.8 Final stakeholder workshop (Friday 2nd April, 2004)

The final stakeholder workshop was held on 2nd April at the Agriculture Information Centre, Kibate, Nairobi. The workshop aimed to report to stakeholders on the overall project and on the extent to which its outputs had been completed. A further aim was to facilitate dissemination of findings and to explore opportunities for ongoing dissemination. 38 people attended and full details of the workshop are given in Murdoch (2004). The workshop was officially opened by Dr Joseph Ochieng, Assistant Director in-charge of food crops at KARI, who stressed the importance of IPM and reported that it forms an important part of government policy. The workshop consisted of the following presentations and activities:

Session A. Introduction and welcome

- Objectives of the project. Dr Alistair Murdoch.
- Descriptions of methods used in the project including RRA, longitudinal study, on-station research, participatory on-farm research, dissemination. Dr Jackson Njuguna.

Session B. Scope for alleviating seasonal forage shortages using Crop Protection Technologies

- Controlling maize streak virus disease to improve forage yield. Ben Likuyu.
- Promotion and uptake of MSVD resistant cultivars (KH521, PAN67) in Kiambu. Representatives from Freshco Seeds and PANNAR Seed Company.
- Development of MSVD resistant cultivars at KARI Muguga. Dr Jane Ininda.
- Controlling weeds to improve forage yield. Dr Jedidah Maina.
- The push-pull system for controlling maize stem borer and improving forage yield: The system, Dr Francis Muyecko, ICIPE; On farm studies of the push-pull system in Kiambu, Sam Njihia.
- The impact of livestock on maize head smut disease and weed seed transmission. Dr Jackson Njuguna and Dr Jedidah Maino.
- Forage conservation. Dr David Miano.
- Summary of the main messages on the technologies. Dr Alistair Murdoch.
- Summary of the economic implications of the technologies for farmers. Dr Peter Dorward.

Session C. Dissemination and training

- Dissemination and training activities. Francis Musembe, Grace Mbure.
- Small group discussions and feedback to identify dissemination activities participant stakeholders can undertake.
- Outline of proposed ongoing dissemination through a follow-on project. Dr Peter Dorward.

Full details of the presentations and of participants' feedback on dissemination are given in Murdoch et al. (2004).

4.7.9 Stakeholder meetings on 11 July 2001.

The purpose of the July 2001 workshop was to discuss how the project outputs could best be achieved and to consult the wide range of stakeholders represented. There were 30 participants. Discussion and feedback generated many useful points. Full details of presentations, discussions and participants are given in Murdoch (2001). Topics covered included: experience from related projects; findings from the initial

RRA; Activity 1.3 Proposals for Longitudinal study; Outputs 1 and 2 On-station experiments; Activity 1.4 Experimental programme to assess forage yield and quality; Activity 2.1 On-station trials to assess disease and weed transmission to subsequent crops after feeding & composting; Output 4 Extensionists and farmers trained.

4.7.10 Stakeholder meetings on 30 September 2002.

The aim of the September 2002 meeting was to consult with the stakeholders and to report on progress and activities since the last stakeholder meeting. One aim was also to broaden the dissemination of project outputs and to invite comments from others. The project therefore funded Dr John Muthamia or his representative from KARI-Embu to be attend this and various subsequent activities of the project. In addition, we paid for Prof Louis Mtenga, from Tanzania to attend this workshop. An MSVD expert from Uganda was also invoted but unable to attend. In total, 28 people attended and full details are given in Murdoch, Njuguna & Owen (2002). The following presentations and discussions took place:

Related projects

- Charles Gacheru of PANNAR Seeds explained their breeding programme and the suitability of the MSVD resistant cultivar, PAN67, to Kiambu was highlighted.
- John Njoroge, Director of Kenya Institute of Organic Farming expressed their interest in this project and in disseminating outputs from it through their many links with farmers through their training college.

Field Experiments

- Results were presented for the 2001/2 short rains season. Dr Njuguna emphasised that these were preliminary results based on a single season.
- Effect of planting density and MSVD. Ben Lukuyu.
- Weeds and weeding regimes. Ben Musembi.
- Passage of spores and weed seeds through livestock. Dr Njuguna.

Longitudinal study

Jedidah Maina explained the process involved and gave some preliminary results.

Dissemination routes

Jackson Njuguna indicated possible routes which were then discussed. For project R7955, the clear message was to link into existing farmer groups rather than trying to establish new ones. The question of what constitutes a good training programme was raised especially in a project of limited size and resources. A good strategy was felt to be to select a limited number who would be able to train others ie the extension service and NGOs.

Add-on project.

Dr Alistair Murdoch explained the aims and objectives of the add-on project.

4.7.11 Leaflets and information sheets for extension staff and farmers

A leaflet explaining the research project “Integrated Weed, Pest and Disease Management of Maize Forage Dairying” was produced in 2003 and has subsequently been revised and updated in June 2004. (Appendix 6)

A leaflet titled "Get more and better forage from maize" for extension staff, NGOs and farmers was produced in time for the final stakeholder workshop. This outlines the main extension messages for each of the key technologies investigated in the project. The leaflet was pretested with farmers and extension staff in January 2004 and feedback incorporated. A version in Kikuyu is currently being printed. (Appendix 8)

Leaflets on the improved maize varieties KH521 and PAN67 produced by Freshco Seeds and PANNAR respectively were also distributed at the final workshop.

A colour information sheet on Maize streak virus which explains what the disease is, its effects, how it spreads and methods of reducing incidence, was produced in 2004. This was adapted with kind permission from a sheet produced under a joint scientific arrangement between the Ugandan National Agricultural Research Organisation and NRI, UK. (Appendix 7).

4.7.12 Project website

A project website was set up in 2003.

http://www.apd.rdg.ac.uk/Agriculture/Research/CropScience/Projects/IntegratedWeed/index.htm

By 29th June 2004, the site had received 4,493 successful requests i.e. 'hits' (an average of 12 per day) and 296.33 megabytes had been transferred (an average of 861.80 kilobytes per day).

4.7.13 Other publications

A list of all reports, presentations at conferences and miscellaneous leaflets etc. is included in Appendix 9.

4.7.14 Conclusion

The project worked closely with farmers, extension and NGOs throughout and from its initial stakeholder meeting. Regular interaction with stakeholders and the stakeholder meeting in 2002 enabled activities to be adjusted where necessary to increase effectiveness. Many of the projects 'activities were participatory in nature and conducted with farmers. Results from 'on station' research have been summarised and communicated as extension messages. Specific activities including the farmer and extension training days and the final stakeholder workshop enabled presentation and discussion of the main findings to farmers, extension workers and other promotion partners. Dissemination concentrated mainly on Kiambu District and scope exists to work with farmers and organisations in similar agroecological zones to adapt and disseminate technologies. This project did achieve some wider dissemination to Embu via formal link with KARI there (John Muthamia) and also by involving KIOF and Land O'Lakes in our field days and workshops and some internal planning meetings. An informal link in Tanzania was also established by facilitating Prof Mtenga to attend our second Stakeholder Workshop.

A short follow-on dissemination project that has recently been approved for 2004-5 will encourage more widespread, sustainable and longer term dissemination activities by promotion partners.

5 Acknowledgements

Although not listed on the cover page of this report, this project was a team effort from start to finish and the contributions and wonderful team spirit of the whole project team listed in Appendix 1 is gratefully acknowledged. Some have joined the team and others have had to leave as time progressed but the magnificent efforts and co-operation between members of this highly diverse, multi-disciplinary team has made it a pleasure to visit Kenya and work together.

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.

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We are also most thankful to Mr Godfrey Mboro for hosting one of the MSVD experiments on his farm at Kanjuko, Githunguri.

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Muthure:

Peter Kuheria; Moses Njuguna & Rose Ndeti; John Kamau & Eunice Wanjiru; George Kimani & Edith Wangari; John Mungai Mate & Mary Wairimu; Milical Nyambura; Samuel Muigai & Elizebeth Wanjiru; Peter Waweru Njau.

Kamburu:

Patrick Kimithia Kamau; Wanyoike & Nancy Wanjiru; Joseph Kimani Mbugua; Peter Nduati & Mary Njoki; John Ngubi & Mary Njeri; James Mbugua Njuguna & Serah Njeri; Stephen Kinyanjui & Lydia Kinyanjui; John Mirie;

Kiaria:

Peter Guthundi & Josephine Wambui; Daniel Waitaro & Phyllis Wambui; Alex Njoroge & Joyce Njoroge; John Ndungu & Serah Wambui; George Ngaruiya & Ruth Wanjiku; John Ndicu & Jane Wairimu; Mbugua Gathungu & Agnes Nduta; Daniel Njuguna & Elizabeth Wacege

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6 References

Note: references to project publications are not included here as they are listed separately in Appendix 9.

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APPENDIX 2a: Materials and Methods for work on MSVD from Lukuyu *et al.* 2005a.

MATERIALS AND METHODS

The study was carried out at Kenya Agricultural Research Institute (KARI), Muguga, Kenya at an altitude of 2095 m above sea level. KARI Muguga is 27 km north of Nairobi and lies at latitude 1^0 13' South, and longitude 36^0 38' East. KARI Muguga receives on average 950 mm of rainfall per annum, with the April - July period receiving 60 %, and the October - November period 40 % of the precipitation. The minimum and maximum average temperatures are 9.8 ^{0}C and 21 ^{0}C respectively. The soils are humic nitisols which are dark reddish brown in colour, well drained, shallow, and moderately fertile (Kiambu District, 1994 - 1996).

Planting

Experimental area was sloping gently and blocks and plots within blocks were arranged across the gradient. Plot sizes of 4 x 4 metres were measured. This allowed 6 rows per plot and 14 holes per row. Plantings were at a spacing of 75 cm between rows with 30 cm between holes within rows. Four seeds were sown per hole and thinned to two healthy plants per hole ten days after emergence. Plots were intercropped with beans in accordance with local farmer practice. The local variety of beans 'Mwitemania' was planted. The beans (2 seeds/hole) were planted equidistant between maize rows and a spacing of 30 cm between plants. Although bean yield was quantified it was not considered a factor in the experiments.

Experimental designs

A summary of the experimental designs and details of factors between seasons are shown in Table 1. In the short rains season 2001, the experiment was factorial with respect to time and cultivars but fertiliser levels were unbalanced. In the long rains season 2002, the experiment was factorial while in short rains 2002, the experiment was factorial with respect to cultivar and time of infection but fertiliser and plant density were unbalanced.

Table 1: A summary of experimental designs and details and factors

Parameters	Short season 2001	Long season 2002	Short season 2002
Design (completely randomised)	4 times of infection x 3 cultivars x 2 fertiliser levels	3 times of infection x 3 cultivars	2 times of infection x 2 cultivars x 4 fertiliser levels x 3 planting densities
Cultivars	Gikuyu, H511 and KH 521	Gikuyu, H614 and KH 521	H511 and PAN 67
Fertiliser levels	Farmer and recommended	Farmer	Zero, farmer, recommended and manure
Infection times (days post emergence*)	0 (Uninfected control), 14, 35 and 56	0 (Uninfected control), 14, and 35	0 (Uninfected control) and 14
Target infection levels (%)	100	100	100
Actual infection levels (%)	92	65	94
Planting density	2	2	1, 3 and 5

(seeds per hole)			
Number of blocks	4	4	4
Number of plots	48	32	80

* Complete emergence was considered when 90% of plants had germinated.

Maize cultivars

The H511 and H614 cultivars were planted in the short and long rains seasons respectively because they are suited to the two seasons. Both cultivars are widely planted in medium-altitude areas of Kenya. The local landrace (Gikuyu) is selected and re-cycled by farmers while KH 521 is a variety resistant to *Maize streak virus disease* (MSVD) bred by KARI. Certified seeds of H 511 and KH 521 were planted while uncertified seed of Gikuyu was obtained from farmers in the study area who had saved it for two years. Gikuyu is an open pollinated cultivar. In the short rains season 2002, the local landrace Gikuyu was dropped. A resistant cultivar PAN 67 was planted since seed for KH 521 could not be secured.

Fertiliser rates

Two levels of fertiliser were applied at planting time. In the short rains season 2001, the local recommended rate (50 kg of N and 50 kg P_20_5 without top dressing) and farmer rates (50% of recommended rate) were applied. In the long rains season 2002, the farmers' rates were reduced to (26.7 kg/ha of N and 10.4 P_20_5), to reflect farmer practice since the results from short rains did no show any clear fertiliser effects. Estimates for farmer rates were done through farmer discussions with the smallholder maize farmers in the study area showed that farmers applied 36 - 57.6 kg/ha of di ammonium phosphate (18:18:0) (SDP, unpublished report 2001). In the short rains season 2002, the local recommended rate, farmer's rate, manure and a zero fertiliser control were applied. A more extreme treatment zero fertiliser level was included to test the hypothesis that fertiliser modifies the effect of disease on maize forage and grain yield. The common farmer practice of two handfuls of dry manure per hole was applied. (I handful weighed an average of 103g hence 206g/hole). This translated into 9.2 DM t/ha. A dry mixture of sheep, goats and cow manure was used.

Cropping calendar

Planting was during the short-rains growing season (October to December, 2001) and repeated in the long and short rains growing seasons (May to August 2002) and (October to December 2002) respectively. However, in the 2001 short rains season rainfall was insufficient and the crop was irrigated, once weekly, from four weeks post-emergence to maturity. A policy was made not to irrigate subsequent experiments in the long and short rains season 2002 and hence the crop was rain fed. Details of the cropping calendar and other operations are shown in Table 2.

Table 2: The cropping calendar showing agronomic practices for all experiments

Activities	Planting seasons		
	Short rain 2001	Long rain 2002	Short rain 2002
Previous crops on the experimental site	Fallow for 2 years with different species of grass - predominantly star & couch grasses	Maize under breeding experiments	Maize under breeding experiments
Seedbed preparation	Tall grass was mowed down, Ploughed once and harrowed twice a month	Ploughed once and harrowed once a month before	Ploughed once and harrowed once a month before

	before planting	planting	planting
Date of planting	5/11/01	25/04/02	24/10/02
Type of inputs at planting	Fertiliser, Maize seeds, 'bulldock' pesticide*	Fertiliser, Maize seeds, 'bulldock' pesticide*	Fertiliser, manure, maize seeds, 'bulldock' pesticide*
Date of weeding	23/11/01 and 8/12/01	5/05/02 and 28/05/02	24/12/02 and 21/01/03
Dates of thinning	Gikuyu - 28/01/2002 H 511 - 11/02/02 Muguga - 26/02/02	Gikuyu -23/7/02 H 614 - 6/8/2002 KH 521- 6/8/2002	Four thinnings done on: 30/12/02, 18/01/03, 31/01/03, 21/02/03
Dates of harvesting	20/04/02	7/10/02	20/03/03

* Applied to protect against maize stalk borer pest.

Culture of leafhoppers and MSV

A transmitting strain of leafhoppers *Cicadulina mbila* was used throughout. The *C. mbila* colony used in transmission studies was a direct descendant from an earlier strain used by Storey and Bock. Nonviruliferous *C. mbila* was caged on healthy pearl millet (*Pennisetum americunum*) in insect-proof cages in glasshouses, maintained at 25^{0}C by means of an electric fan heater. Two days before the inoculation, adult leafhoppers were transferred to insect proof cages containing MSV infected young maize. All plants in each plot were infected artificially by attaching a vial with two infective leafhoppers to the lowest leaf of each maize plant. A 100% infection rate was applied but, the actual percentage infection achieved was 92%. In both short rains seasons whole plots including guard rows were inoculated. However due to insufficient leafhoppers in the long rains 2002 only the final harvest area could be inoculated. Vials containing infective hoppers were attached to the first two blocks and moved to the last two blocks after 24 hours. As a result an actual percentage infection of 65% was achieved in the final harvest area. In short season 2002, an actual percentage infection of 94% was achieved. In all seasons, Furadan [5% $^w/_w$ Carbofuran], a systemic insecticide/nematicide, was applied to control (non-inoculation) plots to minimise infection by the natural population of leafhoppers. In the short rains 2001 and 2002, only 2 and 1% infection respectively of control plants was recorded. However in the long rains season 2002, 26% infection was observed in control plots.

Thinning regimes

To determine forage off-take as thinnings in short 2001 and long 2002 rain seasons, plots were thinned to one plant per hole when at least 90% tasselling had occurred on both healthy (uninfected) and infected plots. Population counts of tasselled plants were taken weekly from both net and guards plot areas to determine tasselling percentage. In the short season 2002, plant density treatments included one, three and five seeds per hole. Thinning regimes were carried out to mimic the common farmer practice in the study area. . One seed per hole treatment was not thinned at all while the three seed treatment was thinnined at knee high and tasselling stages. The five seed treatment was thinned at knee high, tasselling, milk and cobbing stages. Details of the thinning regimes are shown in Table 3. All plots belonging to the same cultivar were thinned at the same time at every thinning stage. The smaller of the two plants in each hole was always thinned. One plant per hole was taken through to final harvest. Final harvest comprised the inside four rows of each plot excluding two holes on each end of each row. The area excluded was regarded as the guard area. Biomass of forage (thinnings and stover) and also cobs and grains were assessed from the final harvest area.

Table 3: Thinning times and characteristics of thinning regimes in all seasons

Thinning times	Growth stage at thinning	Short rain 2001 and long rains 2002	Short rains 2002	Identifying characteristics
		days after emergence		
1st	Second weeding (knee high)	none	14 (2 weeks)	4th leaf visible
2nd	Tasselling	56 (8 weeks	56 (8 weeks)	(16th leaf visible) Tips of many tassels visible
3rd	Milk stage	none	78 (12 weeks)	About 2 weeks (12 days) after 75% silking
4th	Cobbing stage	none	90 (14 (weeks)	About 3weeks (24 days) after 75% silking

Thinning and stover yield estimate

Dry matter (DM) yield of forage, as thinnings and dry stover, were measured; grain yield was also measured. Total fresh weights of maize thinnings and stover of the final harvest area per plot were measured in the field using a sufficiently accurate spring balance. The number of plants harvested from each plot was counted and recorded. In the case of thinnings, infected and uninfected plants in plots were counted and weighed separately to determine the proportion and yield of infected plants in each plot. Forage samples for analysis were obtained from the maize thinnings and stover after weights had been taken. Four to five maize plants were randomly sampled from each final harvest area. They were weighed to determine fresh weight, labelled and immediately placed in plastic bags to reduce moisture loss. Infected and uninfected materials were kept separately. Samples were transported to the laboratory after 2-3 three hours and fractionated into leaf, stem (sheath and tassel) and green cobs. The partitions were weighed and chopped separately. A sub sample of about 500g of fresh material of each partition was collected for DM determination. Plots were harvested differently when cultivars attained physiological maturity when husks and most of the leaves were senescent.

Grain yield estimate

The fresh weight of maize on the cob in each plot was measured. Fresh maize on the cob was shelled by hand separately for each plot. The fresh weights of grain and cobs were measured separately. The grain and cobs were then sun dried separately to constant weight by weighing daily. The final yield was recorded from the final harvest area basis for both forage and grain. Grain and cob samples amounting to about 250g were taken and dried in a draft oven to constant weight at 65^{o} C. DM % of samples was used to calculate DM yield of grain.

3. STATISTICAL ANALYSIS

All data were entered and processed into a Microsoft Excel spreadsheet (Microsoft Corporation, 2000). All the data were analysed using the Genstat statistical package (Genstat. 2000) and subjected to ANOVA by unbalanced design using Genstat regressions. F values for main effect means and their interactions were considered significant at the P<0.05 level.

APPENDIX 2b: Materials and Methods for work on MSVD from Lukuyu *et al.* 2005 b (draft).

Methodology

The studies were carried out at two sites, the Kenya Agricultural Research Institute (KARI), Muguga and Githunguri division, Kenya. Both sites, KARI, Muguga at an altitude of 2095 m and Githunguri division at an altitude of 1801 m meters above sea level are within Kiambu District which lies between latitudes 00 25’ and 10 20’ South, and between longitudes 360 31’ and 370 15’ East. The altitude ranges from 1200 - 2500 metres above sea level. The District receives on average 800 mm - 1400 mm of rainfall per annum, with the April - July period receiving 60 %, and the October - November period 40 % of the precipitation. The soil types are predominantly nitisols with some vertisols in southeastern parts (Kiambu District, 1994 - 1996). Plot sizes of 4 x 4 metres were measured with rows running across the gradient. This allowed 6 rows per plot and 14 holes per row. Plantings were at a spacing of 75 cm between rows with 30 cm between holes within rows. Four seeds were sown per hole and plant thinned ten days after emergence to maintain two plants per hole. Plots were intercropped with beans to simulate farmer practice. Maize was planted on three different dates. The first planting (P1) was at the onset of rains. 100% crop emergence occurred on 8th April 2003, the second planting (P2) was done 9 days after onset of rains while the third planting (P3) was done 14 days after onset of rains. Details of the crop calendar are shown in Table 1.

Two experiments were set up. Experiment 1 was set up in short rains season 2001 and Experiment 2 in long rains season 2003. Experiment 2 was set in Githunguri on two different sites; at the Waruhiu farmers training centre (FTC) and on a farmer’s field. The purpose of setting up the experiment at two sites separated by a distance of about 20 km apart was to increase chances of natural infections since these are unpredictable.

Table 1: The cropping calendar showing agronomic practices for all experiments

Activities	Experiment 1- (Short season 2001)	Experiment 2 - (Long season 2003)			
		Site	P1	P2	P3
Previous crops on the plot	Fallow for 2 years - different species of grass star & couch grasses	FTC	Fallow for one year		
		Farmer	Maize and beans		
Seedbed preparation	Ploughed twice and harrowed once before planting	FTC	Ploughed once and harrowed once before planting		
		Farmer	Hand digging once		
Planting date [a]	5th November 2001	All	31st March 2003	7th March 2003	14th March 2003
Date of weeding	29th November 2001	All	15th March 2003	21st March 2003	30th march 2003

Thinning date	11th February 2002	All	25th July 2003	12th August 2003	22nd August 2003
Thinning days	98	All	106	117	120
Harvesting date	20the April 2002	All	24th Sept. 2003	4th October 2003	21st October 2003
Harvesting days	166	All	167	170	180

[1]P1 - planting at onset of rains
[2]P2 - planting 9 days after onset of rains
[3]P3 - planting 14 days after onset of rains
[a] Beans planted on the same date

In experiment 1, treatments, with three replicates, included 4 infection times x 2 infection levels plus an uninfected control in a completely randomised block design, The MSVD susceptible variety H 511 was planted. The H 511 is one cultivars commonly planted in medium-altitude areas of Kenya. In experiment 2, treatments, with four replicates, included 3 planting times x 2 cultivars in a completely randomised block design. The MSVD susceptible variety H 614 and resistant PAN 67 were planted. H511 and H614 are recommended for short and long rains respectively. In experiment 1, rainfall was insufficient and the crop was irrigated, once weekly, from four weeks post-emergence to maturity.

In both experiments, nutrients were supplied through di-ammonium phosphate (18:18:0 NPK). The fertiliser was applied as a basal dose at the time of planting at the rate of 26.7 kg/ha of N and P. No additional top dressing was applied. In experiment 1, artificial inoculation was carried out, three times of infecting with MSV, 14, 35 or 56 days after emergence, were compared. An uninfected control was included. Additionally, two infection levels, 25 and 100% by maize streak virus, were compared. In the case of the 25% treatment, 25% of the plants were numbered and randomly selected for infection. A transmitting strain of leafhoppers *Cicadulina mbila* was used. Leafhoppers were reared in insect-proof cages in glasshouses. Three days before the inoculation, adult leafhoppers were transferred to insect proof cages containing MSV infected maize. Plants were infected artificially by attaching a vial with two infective leafhoppers to the lowest leaf of each plant. A 100% infection rate was applied. Furadine [5% $^{w}/_{w}$ Carbofuran], a systemic insecticide/nematicide, was applied to control (non-inoculation) plots to prevent infection by natural population leafhoppers. In experiment 2, natural populations of leafhoppers were relied on for natural incidences of infection. A scale of 0-5 was used for MSVD symptom rating on maize (Njuguna, 1986), where 0= no streaking, 1= very few streaks, 2= light streaking, 3= moderate streaking, 4= severe streaking on at least 60% of the leaf area and 5= severe streaking on at least 75% of the leaf area plus plant stunting and leaf tearing.

To determine forage off-take as thinnings, plots were thinned to one plant per hole when at least 90% tasselling had occurred on both healthy (uninfected) and infected plots. Population counts of tasselled plants were taken weekly on whole plot basis to determine tasselling percentage. All plots belonging to the same cultivar were thinned identically at tasselling stage. The smaller of the two plants in each hole was thinned. One plant per hole was taken through to final harvest. Final harvest comprised of four rows excluding two outer ones of ten holes per row excluding two holes on each end. The area excluded was regarded as the guard area. Biomass of forage (thinnings and stover) was assessed from the final harvest area. Plots were harvested on the same day at physiological maturity when husks and most of the leaves were senescent.

DM yield of forage, as thinnings and dry stover, and grain yield were measured. Total fresh weights of maize thinnings and stover per plot were measured in the field using a sufficiently accurate spring balance. The number of plants harvested from each plot was counted and recorded. In the case of thinnings, infected and uninfected plants in plots were counted and weighed separately to determine the proportion of infected plants in each plot. In experiment 1 at KARI Muguga and experiment 2 at Waruhiu FTC site, being government centres, all the harvest from plots to determine yields was taken away. Hence, fresh maize on cob was shelled by hand separately for each plot. The fresh weights of grain and cobs were measured separately. The grain and cobs were then sun dried separately to constant weight by weighing daily. The final yield was recorded from the final harvest area basis for both forage and grain yield. However, on the farmer's field it was agreed before the onset of the trials that the farmer would retain all the harvest. As a result, fresh grain on cob was weighed from each plot. Grain yield was estimated from the weight of maize on cob by determining the cob: grain ratios from samples collected from each treatment. DM samples of cob and grain were estimated from single samples from each plot by drying to constant weight at 60o C. Beans were harvested, weighed on haulms and allowed to dry fro a week. Dry beans on haulms were weighed before threshing. After threshing, beans and haulms were weighed separately and a bulk sample taken to estimate DM.

Forage samples for analysis were obtained from the maize thinnings and stover after weights had been taken. Four to five maize plants were randomly sampled from each final harvest area. They were weighed to determine fresh weight, labelled and immediately placed in plastic bags to reduce moisture loss. Infected and uninfected materials were kept separately. Samples were transported to the laboratory after 2-3 three hours and fractionated into leaf, stem (sheath and tassel) and green cobs. The partitions were weighed and chopped separately. A sub sample of about 500g of fresh material of each partition was collected for DM determination. Grain and cobs samples amounting to about 250g were taken for DM determination used to calculate DM yield of grain.

Data analysis

All data were entered and processed into a Microsoft Excel spreadsheet. Data recorded for quantitative characters were statistically analysed using the Genstat statistical package GENSTAT 6.1 Release software package (Genstat, 2000) and subjected to Analysis of variance (ANOVA) by unbalanced design using Genstat regressions to determine the differences between treatments under study. F values for main effect means and their interactions were considered significant at the $P<0.05$ level.

APPENDIX 3: Materials and Methods for work on Weeding Regimes from Maina *et al.* 2003.

The study was carried out at the National Agricultural Research Centre, Muguga 27 km NW of Nairobi, latitude 1° 13' South, longitude 36° 38' East, altitude 2096 meters above sea level. The area receives on average 900 - 1000 mm rainfall annually in two distinct seasons: - long rains (mid March to June) with an average precipitation of 550 mm and the short rains (mid-October to December) with an average of 400 mm. Temperature ranges are, minimum 7°C maximum 24°C, mean 15°C. The agro-climatic zone is subhumid. The soil is a well drained, very deep, dark reddish brown to dark red, friable clay classified as humic nitisols. The experiment commenced during 2001/2 short rains.

The plots were ploughed and harrowed to produce a good tilth for maize. The experiment was laid out as a randomised complete block design replicated four times with a plot size of 4 m x 4 m. Soil samples were taken before sowing in each plot and analysed for pH, organic C, N, and available P and K (Okalebo et al., 1993). The treatments included four weeding regimes: weed free (W1), weedy (W2), pre-emergence herbicide (W3) and hand weeding twice (W4), two and six weeks after emergence. Two maize planting densities were also tested for all weeding regimes, that is, D1: 9 plants m-2 (2 plants hill-1) and D2: 18 plants m-2 (4 plants hill-1). The maize (cultivar H511) was planted in furrows spaced at 75 cm x 30 cm. Beans (GLP2; rose coco) were planted between maize rows, in all plots at 2 plants hill-1 and also at a spacing of 75 cm x 30 cm. Double Ammonium Phosphate (DAP: 18:46:0, N: P: K) fertiliser was applied before sowing at a rate of 25 kg ha-1. Immediately after sowing beans and maize, pre-emergence herbicides (Alachlor 48 EC at 1.2 kg a.i. ha-1 and Linuron at 0.6 kg a.i. ha-1) were applied using a Knapsack sprayer in W3.

Ninety-six days after emergence (DAE) at 100% tasseling when the crop has reached maximum vegetative growth, the maize was thinned to 1 plant hill^{-1}. Total fresh weight of thinnings in each plot was determined. At maturity, (132 DAE), maize stover was harvested and its fresh weight determined. The fresh weight of shelled maize grain was taken. Ten plants per plot of thinnings and stover were sampled. These were separated into the vegetative (leaves and stems) and reproductive parts (cobs and husks), and oven dried at 60°C to constant weight to determine dry weights. The dried thinnings and stover samples were ground for quality analyses. The digestibility was determined using Pressure Transducer Technique (PTT). The crude protein was determined using Kjeldahl technique (Anderson and Ingram, 1989).

Weed species identification and quantification was done 14 and 42 DAE using three quadrats (0.5 m x 0.5 m) per plot. Fresh and oven dried (at 60°C) weights were determined. At the end of the season the weeds in the experimental area were harvested, sorted into edible and non-edible species and their fresh weights taken. A sample of 500 g of each of the main edible species was taken, dried at 60°C prior to determining dry matter and forage quality (crude protein and digestibility as described above). Times taken to weed each plot (16 m^2) were assessed and converted to man-days ha^{-1} (1 man-day = 8 hours) and the cost of weeding per hectare estimated assuming a payment of 158 Kenyan Shillings (KSh) per man-day. The cost of chemical weed control was KSh 5000 ha^{-1}.

The experimental treatments were repeated on exactly the same plots for a second season (the 2002 long rains). In the third season (the 2002/3 short rains) the same plots were used again but all plots were hand-weeded to quantify residual benefits from the previous two seasons' weeding regimes in terms of weed infestations and hand-weeding times. Plots were irrigated in the first season but not in the second or third. Results from the second season and for the two planting densities are not presented in this paper. Analysis of variance was done using GENSTAT (Genstat 5 Release 3.2 Lawes Agricultural Trust, Rothamsted Experimental Station, 1995). Significantly different means ($P = 0.05$) were separated using SED values.

APPENDIX 4: Protocol for Participatory Evaluation Of Push-Pull: Stage 1

This is the shorter protocol that was followed in Karweti following the use of a longer version with the Kamari Womens' Group, which took too long to apply. During the revision, some questions were removed and detailed instructions were replaced with bullet points and graphics to make it easier for the facilitator to follow.

a) ICE BREAKER ½ HOUR [in field at push pull demonstration patch].

i) After introductions, ask farmers to explain to visitors what is happening on the patch.

ii) Questions:

- *what interests you most about this push-pull system?*
- *does anyone think they might adopt it on their own farm?*

iii) *Here we have one patch* (If it has not already come up, define the meaning of a "patch"). *with the push-pull system. It would be interesting to discuss what the impact (or an equivalent word) might be of using this push-pull system on one patch of your own farm. Let's go back to the hall and explore this idea.*

b) MAP THE ROTATIONS AND CHANGES [after adopting push-pull] 1hr

i) *If you adopt the push-pull system even on one patch, it is not just a one-season change. If you have Napier on your farm, how long do you keep it?*

Establish that the system would need to stay in place for at least 4 seasons. Also confirm (if asked) that not just maize but other crops can be grown in the push-pull.

ii) Think of a maize patch that you have on your farm right now, one that does not have the push-pull system on it.

Display paper with 4 blank rectangles. Ask for one farmer to describe the maize patch she/he has in mind.

Patch 20ft x 20ft Maize cv. H511 beans
Potatoes
Maize cv. H511 beans
Etc.

- How big is the patch?
- What maize cultivar is she growing?
- Is there an intercrop – or more than one? if so, what?
- Is there any Napier in the plot? If so, where is it?

As information is provided, note it in the first "patch". (If more than one farmer wants to provide information, use this as an opportunity to suggest another session at a later date).

What do you plan to grow on the patch next season? (go through the same exercise for the next rectangle).

What might you grow in the season afterwards? (go through the same exercise for the next rectangle).

And finally, for a fourth season, what might you grow?. (Go through the same exercise for the fourth rectangle).

iii) *Now let's look at what would change if you used push-pull on this patch.*

Produce a second set of rectangles on flip chart paper and hang them beside the rotation for the first farmer.

Maize cv. H511 beans

Think about push-pull demonstration patch.

Where is the Napier?
Where is the Desmodium?

In your patch

- *where the Napier would go*
- *where the* Desmodium *would go*
- the maize cultivar
- the intercrop.

What would be in the patch in the next rotation? Explore whether the crop expected in the rotation could be grown in the push-pull system or would need to change. If it needs to change, what crop would be the most sensible and acceptable as a replacement.

Repeat exercise for each stage of rotation.

---

iv) *You can see that when you introduce push-pull, there will be different outputs from your patch because you have different crops on it and you will need extra inputs to grow the Napier and* Desmodium*.*

If you are deciding whether to introduce push-pull, you will want to know how the outputs and inputs might change.

The demonstration patches outside will help you to see and measure the effects for two seasons. On these demonstration patches we are growing only maize and beans in the control, and on the push-pull patch we are also growing Napier and Desmodium*, but we shall not grow any other crops during these two seasons. So this demonstration is not exactly like your patches at home, but it will still help you to see the effect.*

Draw a 2-season rotation for the demonstration patches, both the control and the push-pull (again using rectangles, with the same cropping pattern repeated in 2 seasons).

c) SEASONAL CALENDAR OF ACTIVITIES AND LIST OF ACTIVITIES FOR THE SEASON 1hr

i) To measure the effect of the push-pull, we need to know when different things will happen on the patch.

Draw a seasonal calendar with a section for activities in each crop and get farmers to say when the activities will occur.

e.g. (not complete or accurate)

ACTIVITIES	Mar	Apr	May	Jun	Jul	Aug	Sep	Etc for 2 seasons
Napier	Land prep & manure	Plant				Harvest		
Desmodium		Plant			Harvest			
Maize	Land prep & manure	Plant		Weed		Weed & thinning	Harvest grain and stover	

ii) We can see from the calendar what inputs and outputs will need to be recorded and when.

What do we need to do and to record this season?

Make an activity schedule for this season, from the start of the season.
Make sure that the following are introduced for discussion:

- labour
- seeds and seedlings
- fertiliser and manure
- details of what will be harvested, including forage from maize
- The last item on the schedule is to make the next season's activity schedule.

For example,

WHEN	WHAT	WHO DOES	WHO RECORDS	WHAT IS RECORDED
April	Plant Napier	Farmers + researchers	Farmers	Date Napier canes used Manure used Labour for planting
	Plant maize	Farmers + researchers	Farmers	Date Seeds and cultivar Fertiliser or manure Labour
	Plant desmodium	Etc	Etc	Etc
June	Etc etc	Etc	Etc	Etc
July	Etc etc	Etc	Etc	Etc
August	Etc etc	Etc	Etc	Etc
Sept	Harvest maize Make calendar for next season	Farmers + researchers	Farmers	Grain yield for each cultivar Stover yield for each cultivar Labour
October	Evaluate effects of push-pull	Etc	Etc	Etc

APPENDIX 5a: Participatory Evaluation Of Maize Trials On Mr Godfrey Mboro's Farm At Kanjuko Githunguri On 5th August 2003.

By: Ben Lukuyu, Grace Nyanyu, Solomon Mwendia and Dr. Jackson Njuguna

A participatory evaluation of the maize trial was conducted at Kanjuko Githunguri on 5th of August 2003. The exercise was carried out on Mr Godfrey Mboro's farm that is hosting one of the two experiments set up in Githunguri division of Kiambu District. The experiments were set up to investigate the effect of cultivar and planting time on the incidences of *maize streak virus* disease (MSVD). The objective of the exercise was to collect farmers' views of the maize trial as pertains to the effect of cultivar and planting time on the incidences MSVD and ultimately both fodder and grain yields. Eight farmers neighbouring Mr Godfrey Mboro's farm, 4 researchers, 1 extension officer and 2 representatives from East African Seed Company Ltd. who market one of the cultivars (PAN 67) being tested in the trials attended and participated in the exercise.

Farmers were asked to state criteria they use in assessing a good maize crop. After listing the criteria they were asked to rank in order of importance. The results are shown in Table 1:

Table 1 Criteria used by farmers in assessing a good maize crop

Criteria	**Rank**
Big cob (for higher grain yields)	1
Absence of disease (especially MSVD and smuts)	2
Early maturity	3
More fodder (varieties with big stalk and more leaves)	5
Grain size (prefer medium size)	4

In coming up with the criteria, the farmers noted that a big cob is an indicator of higher grain yields. Farmers pointed out that due to MSVD and Smut diseases problem in the area they would prefer a variety that is tolerant to these diseases. The attribute of early maturing ensures that they have green maize for roasting and green fodder for livestock much earlier in the season. Early maturing varieties will yield even in seasons with insufficient rainfall. Farmers preferred medium sized grain because they are easy to thresh by hand and are usually preferred where green maize is sold for roasting because they tend to be sweet. Farmers said that they prefer varieties are that are leafier and have big stover (stem/stalk) since they provide more fodder.

Farmers were guided through and shown different trial treatments. They were then asked to state any observations or differences they could note between treatments. The following are the observations that farmers made of different treatments.

1. **PAN 67 had matured earlier than H614 even though they were planted on the same day. PAN 67 was ready to be roasted (had already attained dough stage) while H614 was not (at milk stage).**
2. **Farmers observed that between treatments planted on the same day, H614 had bigger, taller and thick stem as compared to PAN 67 that was short and had a smaller stem. To them this indicated that H614 could produce more fodder. They pointed out that the**

disadvantage of small and weaker stems in area is that dogs take advantage of it to break the stems and destroy green cobs at dough milk/stage. Farmers also noted that PAN 67 had smaller cobs as compared to H614. However they pointed out that although cobs size was an indicator of grain yield the ultimate yield would depend on grain filling.

3. **Farmers clearly observed that regardless of the planting date, H614 had more MSVD incidences that PAN 67. Asked why they think that was the case, they said they thought that PAN 67 was more resistance to *maize streak virus* (MSV) than H614. They also noted that the leaves of H614 showed more MSVD streaks as compared to PAN 67. Some other farmers tried to link this to differences in fertility between the treatments (although this was not true of the experiments). These farmers explained that from observations on their own farms, H614 will still produce good yields on patches that have received continuous application of manure every season i.e. H614 will tend to withstand MSVD when grown on patches that have been receiving high amounts of manure. Later in our next visit one of the farmers took us to his farms and showed us a patch of H614 maize that had over 95% infection but the crop showed fewer streaks and had strong stem and cobs. The farmer assured us that he would get good yields from the crop. The farmer applies all the manure that comes from his 'zero grazing' unit on this patch of land. Clearly farmers picked out that some of the plants especially for H614 variety that had 100% infection were stunted and over showed. And quite rightly they pointed out that the plants must have been infected much earlier than the rest.**
4. **They also observed that the treatments planted latest had a high number of MSVD incidences as compared to the two treatments planted earlier. Asked why they thought this was happening, they responded that late planting would result in increased MSVD since increased infection was coming from the other surrounding infected plants especially if they are not thinned. Some farmers observed that late planting does result in increased incidences even on their own farms. They said implication of this is that they usually end up getting more fodder and less grain since they tend to thin MSVD infected plants. The farmers didn't seem to have any idea that the infection also reduces fodder yields.**
5. **They observed that maize planted earliest (30.1.03) for both varieties was at an advanced stage of maturity as compared to the ones planted later. They stated that the latest planted maize would end yielding more barren plants than plants with cobs. Asked what this would mean for them, they stated that early-planted maize takes advantage of early rains and in case the rainfall turns out to be insufficient they would still get some harvest from an early-planted crop. However where they aim to get mainly fodder than grain they still go ahead and plant late where they have space on some patches.**

Table 2 Farmer scoring results for PAN 67 maize variety at Kanjuko

Farmers	1	2	3	4	5	6	7	8	Total	Weighted score	Score position
Criteria	Individual farmer score points										
Big cobs	4	4	3	4	4	4	2	5	30	8.0	4
Absence of disease	5	5	5	5	4	5	3	5	37	4.9	2
Early maturing	5	5	5	5	4	5	4	5	38	2.5	1
Grain size	5	5	5	5	3	5	2	5	35	7.0	3
More fodder	3	4	3	3	4	4	3	3	27	9.0	5
Total	22	23	21	22	19	23	14	23	167	31.5	

Attribute scoring for varieties

After going through the trial treatments, farmers were asked to score for H614 and PAN 67 against the criteria they had earlier identified. The scoring was done on a scale of 1 – 5 where 1 is poor and 5 is best. The results are presented in Tables 2 and 3

Table 3 Farmer scoring results for H614 maize variety at Kanjuko

Farmers	1	2	3	4	5	6	7	8	Total	Weighted score	Score position
Criteria	Individual farmer score points										
Big cobs	5	5	5	5	5	5	5	5	40	2.7	1
Absence of disease	3	2	3	3	3	4	2	3	23	7.7	5
Early maturing	4	4	3	4	3	4	3	3	28	7.5	4
Grain size	4	3	4	4	2	4	5	4	30	6.0	3
More fodder	4	5	5	5	5	5	5	5	39	5.2	2
Total	**20**	**19**	**20**	**21**	**18**	**22**	**20**	**20**	**160**	**29.0**	

The scoring results show that farmers have almost the same preference for the two varieties although PAN 67 had a slight edge over H614. However each variety has its own strong preferred attributes. PAN 67 is preferred for early maturity and absence of disease while H614 is preferred for its big cob and stalk (more fodder).

Changes that farmers might adopt after seeing and discussing about the trials

Farmers were probed about changes that they might adopt after seeing and discussing about the trials. The following are the changes that they suggest they could make:

1. **They would plant early and at the same time for all their patches on their farms and varieties. This is because a part from what they have observed from their own farms that early planting guarantees yields especially in season with insufficient rainfall, the trials have also showed them that early planting reduces incidences of MSVD and therefore they might get higher yields. Asked what determines their time of planting. They said it is normally determine by**
    a. **Usually on set of rains**
    b. **Availability of seed in the local stores and the variety planted also depends on which variety is stocked.**
    c. **When a farmer gets the money to purchase the seed**
2. **Farmers pointed out that they would introduce PAN 67 as an additional variety to H614 but plant them on different patches. This is because MSVD occurs intermittently (i.e. does not always occur in all seasons). So that in the event of MSVD they will be assured of a grain harvest from PAN 67 and rely on H614 for fodder. In case is there is no MSVD in the season, then they will take advantage of the best attributes of both varieties (some sort of risk aversion). Asked how they would take advantage of the attributes, they qualified that while PAN 67 would mature early and provide green maize for food and fodder for livestock early in the season, H614 is good and preferred for roasting and has ready market in all urban areas. It also prepares sweet local dishes like 'githeri' and 'ugali'.**

Protocol on participatory evaluation of trial at Kanjuko Githunguri 5th August 2003

Word of prayer - farmer

i) Extension staff to introduce evaluation team to the farmers.
ii) State purpose of visit – *The purpose will be to assess and hear what farmers think of the trial.* ***(remember not to introduce why we did the trial until after we hear what they think).***
iii) Facilitator to ask farmers to establish and state criteria for assessing a good maize variety
- o *farmers to rank the criteria in order of importance*

iv) Host farmer to lead team to the trial site
v) Explain to farmers what was done of the experiment

Treatments planted on plot sizes of 4 x 4 metres

Planting dates:

Onset of rains (initial sowing) (31 March 2003)
1 week (7days) after initial sowing
2 weeks (14 days) after initial sowing

Cultivars

Hybrid 614
PAN 67

DAP fertiliser was used. The rate was *120 g/plot, i.e. 36.75 kg/acre or ¾ of a 50 kg bag*

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vi) Invite farmers to tour the plots showing different treatments
vii) Facilitator to alert farmers that they will be required to comment on the treatments
viii) Facilitator to prompt a discussion with farmers at the trial site in order to establish:
- ♦ What observation do farmers make between treatments?
- ♦ What differences do they note in the maize varieties? ***(note avoid mentioning the word disease at this point)***
- ♦ What differences do they note in time of planting?
  - o What do they think happened
  - o What would differences in time of planting mean for them
  - o If disease were less would they plant later? If not why not?
- ♦ Would they feed these diseased leaves to animals?
  - o If not why not?
  - o If yes would they expect any difference between diseased and good leaves?
- ♦ Would they accept a little bit less grain if there was a lot more forage?
- ♦ How do the researcher treatments compare to the way they manage their own maize?
- ♦ If they had been planting what would they have done differently

ix) **AT the plots**, facilitator re visits the criteria for assessing a good maize variety.
- o *She now asks each farmer to score for the varieties against the criteria on a scale of 1-5 scale where 1 is poor and 5 is best.*

Team reassembles back at the farmer's homestead.

x) Facilitator probes about changes that farmers might adopt after seeing and discussing about the trial
Ask farmers to compare what they saw on the trial site with what they see on their farms.
After what they have seen would they change their existing practices, if so how.
How do they decide when to plant
If they observed differences due to planting date would they change their own planting dates - If yes or no – WHY?
What were the most interesting differences they noted – could they explain why they thought these differences were occurring
Ask them what influences the choice between hybrids and local varieties *(discuss the cost of seeds and how important this is to the choice)*

xi) Conclusion
- o Facilitator invites any questions from farmers
- o Closing prayer - farmer

APPENDIX 5b: Participatory Evaluation Of The Dry Maize Grain In Kamari

G.N Mbure, KARI-NARC-MUGUGA

A consumer preference exercise was held with the Kamari women's group on the 15th October 2003 to determine which of the two maize varieties, H511 and PAN 67 would be preferred by farmers in making the local dish known as 'githeri'.

At the beginning of the exercise, the farmers were asked to state the preferred qualities/attributes of a maize grain suitable for githeri. Two main qualities identified were grain size and taste. Farmers said they preferred medium sized grain (as it mixes well with beans) and one that is sweet to taste. Some farmers felt that grain size is more important than the taste as it is often not possible to distinguish the taste of dry maize when prepared as githeri. Further more they indicated that the taste of dry maize is more pronounced in ugali (another local dish) than in githeri.

On the basis of these two criteria, farmers were then asked to score individually for the H511 and PAN67 on a scale of 1-2 points, 1 being poorer and 2 better (Table 1).

Table 1 Scoring results for grain size and taste of PAN67 and H511 Maize Varieties. (1: poorer; 2: better)

Criteria	Grain size		Taste	
	PAN67	H511	PAN67	H511
1	2	1	2	1
2	2	1	2	2
3	1	1	2	2
4	2	2	2	2
5	2	1	2	1
6	2	1	2	1
7	2	1	2	1
8	2	1	2	1
9	2	1	2	1
Total Score	17	10	18	12
Rank	1	2	1	2

Conclusion

Farmers prefer PAN67 to H511 because of its taste and grain size (Table 1). They said that PAN67 was sweeter than H511 and had the desired grain size.

Appendix 6. Four page Project Leaflet – Issued 2003, revised January and June 2004. Final version shown..

Dissemination strategy

In an effort to enhance the uptake of technologies developed, the project adopted the following strategies:

1. **Stakeholder meetings** – to ensure that stakeholders have the opportunity to influence the research agenda and also get a feedback on the results.
2. **Linkages with partners** – working with and training extension providers (public and private). To ensure they are likely to promote the technologies in a sustainable way, additional funding is being sought for training activities in 2004/5.
3. **Farmer field days** – farmer field days to disseminate the findings to the target farmers and extension providers

4. **Farmer exchange visits**
5. **Participatory on-farm research**
6. **Develop dissemination material** – material aimed at extension providers and farmers has been published.
7. **Project web-site**
http://www.apd.rdg.ac.uk/Agriculture/Research/CropScience/Projects/IntegratedWeed/index.htm

Enquiries in Kenya to Dr Jackson [illegible] or Dr David [illegible], KARI-NARC-MUGUGA, PO Box 30148, Nairobi, Kenya. Email: [illegible]

Enquiries in the UK to Dr Alistair Murdoch, The University of Reading, Department of Agriculture, Earley Gate, Reading RG6 6AR. Email: [illegible]

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Project R7955, IPM of maize forage dairying: Renewable Natural Resources Knowledge Strategy Livestock Production (LPP) and Crop Protection (CPP) Programmes. LPP and CPP are managed by Natural Resources International Ltd., Aylesford, UK. 9-Aug-04

Integrated Weed, Pest and Disease Management of Maize Forage Dairying

Left: maize stover at Githunguri. Right: streaked maize

Theme: More forage from maize for more milk

A collaborative research project between the Kenya Agricultural Research Institute (KARI), the International Livestock Research Institute (ILRI), the University of Reading (UK) and (initially) PAN Livestock Services Ltd (UK).

The research team consists of forage and livestock specialists, crop protectionists and socio-economists from both Kenya and the UK.

Apart from the main institutions above, other collaborators include Land O' Lakes and the Kenya Institute of Organic Farming (KIOF).

Project Goal

To improve the livelihoods of smallholders growing maize and producing milk by developing and promoting integrated pest weed and disease management strategies maize that increase the seasonal availability of forage from maize and weeds and hence greater milk production.

Project justification

Dairying is an important source of household income on most smallholder farms in Kenya. However, forage shortage results in low milk production, long calving intervals, high calf mortality and low weight gain in young stock. The shortage of forage is especially pronounced during the dry season.

As land holdings decrease in size due to sub-division, small-scale farmers cannot generate sufficient forage for dairying. In central Kenya it is estimated that Napier grass (*Pennisetum purpureum*) provides only about 40% of the forage and the proportion is decreasing. The maize crop is increasingly being grown continuously for forage as well as food on small-scale farms. Weeds from crop land are also an important source of forage for livestock.

Practices that aim at maximising forage production from the maize crop are being adopted. These include high density planting each season. Some of the plants are then thinned to provide forage for dairy animals. Weeds are also left to grow longer before the second weeding. In addition to the long-term effects of such practices on weed infestations, implications for diseases and pests are being monitored.

Most importantly, this project is investigating the impact of diseases and weeds on the grain and forage yield and quality. Integral socio-economic studies quantify economic benefits of the IPM strategies.

Target group

Farmers that the project is designed to benefit include relatively resource poor small-scale dairy farmers including (where applicable) landless men and women in the Central Kenyan Highlands.

Project activities include

1. The effect of maize cultivars, dense planting and maize streak virus disease on grain yield and forage yield and quality.
2. The effect of different weeding regimes on grain yield and the yield and quality of forage from maize and weeds.
3. Integrated disease, weed and pest management to optimise grain and forage production – including the pull-and-push system of reducing maize stalk-borer.
4. Evaluate farm-level economic implications of IPM strategies
5. Small-scale forage conservation.

All the activities have an on-station and on-farm components. All off-station activities now include farmer participation. The pull-and-push system of reducing maize stalk-borer comprised a preliminary evaluation and further validation is still desirable.

Some Project Highlights

Farmers identified maize streak virus disease (MSVD), maize stem borer and weeds as the three main biotic constraints in Kiambu.

The hybrid cultivars KH521 and PAN67 have performed well on and off-station and are now commercially available. Farmers confirmed that they are resistant to MSVD and that flavour and appearance characteristics are satisfactory. The open-pollinated variety, SADVEB, and local landrace., GIKUYU also had some resistance.

Dense planting maize reduces weeds, but thinning for forage must be carried out carefully to avoid reducing grain yield.

The project has developed and where feasible evaluated options to address three main biotic constraints to maize forage and grain production. An outstanding feature is to provide options to solve these problems in participatory research with small-scale maize-dairy farmers, extensionists, socio-economists, crop protectionists, forage and livestock specialists.

Appendix 7 Four page Information Leaflet on MSVD – Issued 2004

DOES THE TYPE OF MAIZE AFFECT THE LOSSES DUE TO DISEASE?

There are types (varieties) of maize that are resistant to maize streak virus disease. What this means is that although the maize still gets infected with the virus the amount of green leaf lost due to the yellow streaking is very much lower. Good resistant maize will show only a few dots of streaking on each infected leaf. This ensures that the area of green on the leaves is large and a good-sized cob and more forage from maize should result.

Improved hybrid varieties are being developed, which show good resistance to the virus disease. KH521 was developed at KARI and PAN67 by Pannar Seed Company. They are also resistant to other diseases and produce good size cobs and have medium maturation dates. Farmers in Kiambu have found their taste acceptable. Both of these varieties are now available from seed agents. New varieties are also being developed by KARI. Check with Fresco Seed Company for up to date information.

It is important to buy certified seed of hybrids each season, to make sure that the good properties of the varieties, particularly maize streak virus resistance, are retained and not lost due to cross pollination with local varieties.

This leaflet has been revised with permission from one produced under a joint scientific arrangement between the Ugandan National Agricultural Research Organisation and the Natural Resources Institute, UK.

The revised leaflet is an output from Research Project R7955 (IPM of maize forage dairying) which is funded for the benefit of developing countries by the UK Department For International Development (DFID) Renewable Natural Resources Knowledge Strategy Livestock Production (LPP) and Crop Protection (CPP) programmes. The views expressed are not necessarily those of DFID.

Collaborators include Kenya Agricultural Research Institute-NARCentre-Muguga, ILRI, PAN Livestock Services, Kenya Institute of Organic Farming and The University of Reading, UK.

IPM of maize forage dairying website:
http://www.apd.rdg.ac.uk/Agriculture/Research/CropSciences/Projects/IntegratedWeed/index.htm

For further information contact the Director, KARI.

MAIZE STREAK VIRUS DISEASE

AN INFORMATION SHEET

WHAT IS MAIZE STREAK VIRUS?

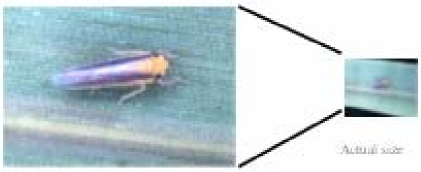
Maize streak virus causes a disease of maize that produces yellow lines on the leaves called streaking. This yellow streaking reduces the plant's ability to grow and to fill cobs. This is because it is through the green parts of the leaf that the maize plant makes its own food. A maize plant cannot be cured once it

Part of a maize leaf showing the yellow streaking caused by the disease

is infected.

HOW DOES THE DISEASE GET INSIDE THE MAIZE PLANT?

The virus is spread by very small insects called leafhoppers, which feed on grasses by sucking their juices. When feeding on maize they can pick up the virus from an infected plant. Once the leafhoppers have the virus inside them, every time they feed on other maize plants they may give those plants the virus. This is like a mosquito picking up the malaria parasite from one person and then passing malaria on to several other people.



Actual size

The leafhopper which carries the streak disease (larger than actual size)

CAN THE VIRUS BE SPREAD IN ANY OTHER WAY?

Only the leafhoppers can carry the virus, other insects cannot carry it. The virus cannot pass through the maize seed or through the soil; only the leafhoppers can spread the virus by feeding on the plants. The leafhoppers are normally found in the wild grasses, which they prefer to feed on and to lay their eggs in.

HOW DOES THE DISEASE AFFECT PLANTS OF DIFFERENT AGES?

It is only the growing leaves that can get the virus disease. So when a maize plant gets the disease only the leaves that have grown after infection show the streaking. The later a plant is infected by a leafhopper the less green leaf area is lost due to streaking and the better the yield from the plant. A plant infected when it is young may die or not produce a cob.

WHAT INCREASES OR DECREASES THE AMOUNT OF DISEASE?

- *Growing maize in the shade of trees*

The leafhoppers like the shade and maize grown in the shade of trees is much more likely to get the streak disease than plants out in the open. For this reason, if possible, it is better not to plant maize in the shade of trees.

- *Time of planting compared with other maize in the area*

The leafhoppers mostly like maize at a height of 25-40cm and it is then that the virus really starts to spread quickly in the fields. A maize field planted later than others in an area may be the only one at the preferred height and more leafhoppers can collect in the field increasing the chances of heavy infection.
At the beginning of the growing season very few leafhoppers are carrying the virus. As more and more maize plants get the virus the number of leafhoppers picking up the virus and spreading it increases. Maize fields planted later than others in an area can have far more plants infected with the disease because there are many more leafhoppers around carrying the virus.

- *Replanting where seeds have not germinated (gap filling)*

Replanting where seeds have not germinated will also increase the amount of streak because of the leafhoppers' preference for the younger plants in the field and because the numbers of leafhoppers carrying the virus will be high by the time these new plants reach the height of 25-40cm. This does not mean that gap filling should be stopped as many of the plants may still produce a cob of some sort, which is better than none at all from empty stands.

- *Removing diseased plants (roguing)*

Removing diseased plants does not really help because there are many leafhoppers with virus spreading the streak and plants that are pulled out may have produced a cob.

- *Growing maize with other crops (intercropping)*

The leafhoppers that carry maize streak virus can fly and are very active. They move close to the ground hopping from plant to plant in a maize field. It may be possible to make it more difficult for the leafhoppers to move around and to find maize plants by filling the space between maize plants by planting a dense intercrop such as beans or millet.

Appendix 8 Six side folded A4 leaflet for farmers and extension use

Six side folded A4 leaflet for farmers and extension use – Pre-tested by farmers on 28 Jan 2004 and by extension on 27 Jan 2004. Issued at Stakeholder Meeting 2 April 2004.
English version shown. Also being prepared in Kikuyu.

Manage your maize crop to produce more forage

- Plant 3-4 seeds of maize per hole.
- Remove the weak plants at knee high and let 1 or 2 grow to give you grain.
- Feed the removed plants to your cow, goats or store and use during the dry season.

After harvesting your maize

- Collect the stover and store it under shade and protect it against termites.

All these methods will increase your forage AND also increase food and money for your family.

This project was undertaken by:

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For more information visit our website www.apd.rdg.ac.uk/Agriculture/Research/CropScience/Projects/IntegrateWeed/index.htm or contact david.kari@africaonline.co.ke

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Get More and Better Forage from Maize

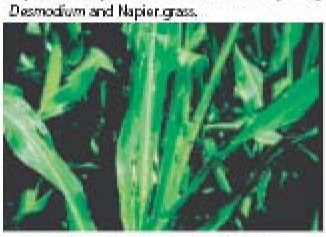
You can get more food and forage from your maize crop by controlling maize streak virus disease, pests and weeds that reduce your yield. Manage your maize crop so that you get more forage without reducing grain yield.

Control maize streak virus disease

Maize streak virus disease reduces grain and forage production as it results in small maize plants and reduces the green colour in the leaves making them yellow.
The best method of control is to plant maize varieties resistant to the disease. Planting early also reduces the effects of the disease on your maize.

Control maize stemborer

Maize stemborer can damage up to half of your maize plants if not controlled. Chemical control is expensive but you can control stemborer by using *Desmodium* and Napier grass.



Use "push-pull" method to control

Plant three rows of Napier grass around your maize crop. Napier grass pulls and traps the stemborer and prevents it from getting into the maize. Plant a row of *Desmodium* between maize rows after every 3 - 5 rows of maize. *Desmodium* repels (pushes away) the stemborer from the maize.

"PUSH-PULL" SYSTEM

Benefits from the push-pull

- It controls stemborers
- Napier and *Desmodium* give good quality forage for your cow or goats.

The extra forage can be stored as silage and used during the dry season

Control weeds

They reduce crop yields

- Weed early so that weeds do not over power your young crop.
- Do not let the weeds flower and go to seed as this increases your weed problem the next season.
- Some of the weeds can be used to feed your cow or goats.

Appendix 9 Project Publications (as of August 2004)

Anon. (2004) Get More and Better Forage from Maize. An Information Leaflet. 3000 copies. KARI Muguga Research Station, PO Box 30148, Nairobi, Kenya and The University of Reading, UK. 4pp. [Information leaflet]	Information leaflet
Anon. (2004) Maize Streak Virus Disease. An Information Leaflet. 500 copies. KARI Muguga Research Station, PO Box 30148, Nairobi, Kenya and The University of Reading, UK. 4pp. [Information leaflet]	Information leaflet
KIVUVA, B.M. (presenter), MBURU M.W.K., MAINA, J.M., MURDOCH, A.J., NJUGUNA, J. and MWANGI, D.M. (2002) The effect of weeding regimes and maize planting density on quantity of maize forage and grain yields. Paper presented at Kenya Agricultural Research Institute 8th Biennial Scientific Conference, KARI Headquarters, Nairobi, Kenya, 11-15 November 2002.	Oral presentation
KIVUVA, B.M., MBURU M.W.K., MAINA, J.M., MURDOCH, A.J., NJUGUNA, J. and MWANGI, D.M. (2002) The effect of weeding regimes and maize planting density on quantity of maize forage and grain yields. 8pp. In: Proceedings Kenya Agricultural Research Institute (KARI) 8th Biennial Scientific Conference, November 2002. KARI, Nairobi, Kenya.	Paper within edited proceedings
LUKUYU, B., MURDOCH, A.J., NJUGUNA, J., MWANGI, D.M., JAMA, A.N., OWEN, E., MOULD, F.L. and ROMNEY, D.L. (2003) Effect of maize streak virus disease infection on yield and quality of forage from maize. Meeting of the Tanzanian Society of Animal Production in Tanga Tanzania 28th - 30th October 2003	Oral presentation
LUKUYU, B., ROMNEY, D.L, MURDOCH, A.J., MOULD, F.L,. MWANGI, D.M., NJUGUNA, J., JAMA, A.N. (2004) Crude protein concentration and neutral detergent fibre content in forage from maize infected with maize streak virus disease at different growth stages. Presented by Lukuyu at 2004 Regional Conference on Animal Production. Meeting of the ANIMAL PRODUCTION SOCIETY OF KENYA, March 2004	Oral presentation
LUKUYU, B.A. (2002) The Effects of Maize Genotypes and Disease on Maize Forage, Grain Yield and Quality in Intensive Smallholder Dairying Systems. 36pp. Upgrading Report to The University of Reading, School of Agriculture, Policy and Development, Reading, UK. (Includes literature review)	Internal Report
LUKUYU, B.A., NJUGUNA, J., MWANGI, D.M. (presenter), MURDOCH, A.J., MOULD, F.L., OWEN, E. and ROMNEY, D.L. (2002) Effects of infection with maize streak virus and cultivar, on yield and quality of maize forage and on yield of grain. Paper presented at Int. Conf. Brit. Soc. Anim. Sci., Amer. Soc. Anim. Sci. and Mexican Soc. Anim. Prod. Responding to the Increasing Global Demand for Animal Products, Merida, Mexico, 12-15 November 2002.	Oral presentation
LUKUYU, B.A., NJUGUNA, J., MWANGI, D.M., MURDOCH, A.J., MOULD, F.L., OWEN, E. and ROMNEY, D.L. (2002) Effects of infection with maize streak virus and cultivar, on yield and quality of maize forage and on yield of grain. Pp. 60-61. In: Responding to the Increasing Global Demand for Animal Products, Programme and Summaries Int. Conf., Merida, Mexico, November 2002. Smith, T. and Mlambo, V. (Eds). British Society of Animal Science, Penicuik, UK.	Scientific Abstract
MAINA, J.M., KIVUVA, B.M., MBURU, M.W.K, MURDOCH, A.J., NJUGUNA, J.M. AND MWANGI, D.M. (2003). Weed management options for resource poor maize-dairy farmers in Central Kenya. Presented by Dr Maina in Poster Session, Crop Production and Protection in Tropical Crops, at Crop Science & Technology Conference, Glasgow, 10-12 November 2003, Poster 7F-2.	Poster display
MAINA, J.M., KIVUVA, B.M., MBURU, M.W.K, MURDOCH, A.J., NJUGUNA, J.M. AND MWANGI, D.M. (2003). Weed management options for resource poor maize-dairy farmers in Central Kenya. Proceedings of the 2003 Crop Science & Technology Conference, Glasgow, 2: 993-998. The British Crop Protection Council, Alton, Hampshire.	Paper in edited proceedings: (editors' names not usually included in citation)

MBURE, G., MUSEMBI, F. AND NJUGUNA, J. (2004) Potential uptake of technologies presented by the IPM of maize forage dairying project R7955 during a farmers' field day at the FTC - Waruhui on 28th January 2004. pp 13.	Internal report
MBURE, G.N. (2003) Participatory evaluation of the dry maize grain in Kamari. [Evaluation by Kamari women's farmer group] [9 farmers, 15th October 2003] [Kikuyu; report in English, 2 pp.]	Workshop and report
MCLEOD, A., NJUGUNA, J., MUSEMBI, F., MAINA, J., MIANO, D.M., ROMNEY, D. and MURDOCH, A.J. (2002) Farmer Strategies For Maize Growing, Maize Streak Virus Disease Control And Feeding Of Smallholder Dairy Cattle In Kiambu District, Kenya. 2001-2002. Results of a rapid rural appraisal held in April and May 2001. First technical report of DFID project R7955/ZC0180. The University of Reading, 34 pp.	Technical report
MCLEOD, A., NJUGUNA, J., MUSEMBI, F., MAINA, J., MIANO, D.M., MURDOCH, A.J. AND ROMNEY, D. (2004) Farmer Strategies For Maize Growing, Maize Streak Virus Disease Control And Feeding Of Smallholder Dairy Cattle In Kiambu District, Kenya. 2001-2002. Results of a longitudinal study. Second technical report of DFID project R7955/ZC0180. The University of Reading, 62 pp.	Technical report
MIANO, D., NJUGUNA, J., and MURDOCH, A.J. (2003) "More Forage from Maize for More Milk". 70 copies. KARI Muguga Research Station, PO Box 30148, Nairobi, Kenya and The University of Reading, UK. 4pp. [Information leaflet]	Information leaflet
MIANO, D., NJUGUNA, J., and MURDOCH, A.J. (2004) Integrated Weed, Pest and Disease Management of Maize Forage Dairying. 30 copies. KARI Muguga Research Station, PO Box 30148, Nairobi, Kenya and The University of Reading, UK. 4pp. [Information leaflet]	Information leaflet
MURDOCH, A.J. (2003). Integrated weed, pest and disease management of maize forage dairying <http://www.apd.rdg.ac.uk/Agriculture/Research/CropScience/Projects/IntegratedWeed/index.htm>	Website
MURDOCH, A.J., MAINA, J.M., KIVUVA, B.M., MBURU, M.W.K., NJUGUNA, J.M. AND MWANGI, D.M. (2004). Impacts of weeds and weeding regimes on maize forage yields and quality for resource poor maize-dairy farmers in Central Kenya. In Abstracts of International Weed Science Congress, Durban, 20-24 June 2004.	Scientific Abstract
MURDOCH, A.J., MAINA, J.M., KIVUVA, B.M., MBURU, M.W.K., NJUGUNA, J.M. AND MWANGI, D.M. (2004). Impacts of weeds and weeding regimes on maize forage yields and quality for resource poor maize-dairy farmers in Central Kenya. Presented at International Weed Science Congress, Durban, 20-24 June 2004.	Oral
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. Crop Quality: Its Role in Sustainable Livestock Production.Aspects of Applied Biology 70: 71-77.'IPM options to improve maize forage yield and quality for small-scale dairy farmers in central Kenya'. Presented by Dr Murdoch at Association of Applied Biologists conference, "Crop Quality: Its role in sustainable livestock production", UMIST, Manchester Conference Centre, 15-16 December 2003.	Oral presentation
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.	Paper in edited proceedings
MURDOCH, A.J., NJUGUNA, J. and OWEN, E. (2002) Report on Stakeholder Meeting on 'Strategies for feeding smallholder dairy cattle in intensive maize forage production systems and implications for integrated pest management', 30 September 2002, Agriculture Information Centre, Kibate, Nairobi. Kenya. DFID RNRRS LPP and CPP Project R7955. University of Reading (School of Agriculture, Policy and Development) and Kenya Agricultural Research Institute /National Agricultural	Internal Report (includes details of several oral presentations

Research Centre (KARI/NARC, Muguga), Reading, UK and Nairobi, Kenya. 8 pp.	on the project)
MURDOCH, A. NJUGUNA, J, AND 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.	Internal Report
MUSEMBI, F. (2002) Feedback from Farmers on Field Day Held on 27 February 2002 at KARI-NARC- Muguga, Kenya. 2pp	Internal Report
MUSEMBI, F. (2003) Push Pull System: Kamburu Exchange Visit to Kamari. [20 farmers, 4th July 2003] [Kikuyu; report in English, 1 pp.]	Exchange training visit and report
MUSEMBI, F. and MBURE, G.N. (2003) Effects of MSVD infection: Kamari and Karweti farmers' groups visit to Kamburu farmers' group. [31 farmers, 13th August 2003] [Kikuyu; report in English, 2 pp.]	Exchange training visit and report
MUSEMBI, F., NJIHIA, S. (2003) Reports on participatory farmer planning activities February to March 2003.	Internal report
NJIHIA, S.N., MUSEMBI, F. and NJUGUNA, J.G. (2002) Report on Visit by a Group of Farmers from Githunguri Division to the Push-Pull Technology in Vihiga District, Kenya, 6-8 November 2002. DFID RNRRS LPP/CPP Project R7955. Kenya Agricultural Research Institute /National Agricultural Research Centre - Muguga, Nairobi, Kenya. 7 pp. Also obtainable from The University of Reading, School of Agriculture, Policy and Development, Reading, UK.	Internal Report
NJUGUNA, J., LUKUYU, B., MAINA, J., MURDOCH, A.J. For participants of R7798 Dissemination Workshop. Held at KARI_NARC_MUGUGA, Kenya	Field day
NJUGUNA, J., MIANO, D., LUKUYU, B.A., MAINA, J., MUSEMBI, B. and METHU, J. (2002) Farmer Field Day on IPM of Maize Forage Dairying. Theme: "More Fodder from Maize for More Milk". KARI Muguga Research Station, Kenya. 27 February 2002. [One-Day Farmer Field Day for 70 farmers] [Swahili and Kikuyu]	Farmer field day
NJUGUNA, J., MIANO, D., LUKUYU, B.A., MAINA, J., MUSEMBI, F., McLEOD, A., ROMNEY, D. and MURDOCH, A.J. (2002) Questionnaire on "More Fodder from Maize for More Milk". 150 copies. KARI Muguga Research Station, PO Box 30148, Nairobi, Kenya. 1p. [Flier] [Field]	Flier
NJUGUNA, J., MIANO, D., LUKUYU, B.A., MAINA, J., MUSEMBI, F., MURDOCH, A.J. (2002) "More Fodder from Maize for More Milk". 150 copies. KARI Muguga Research Station, PO Box 30148, Nairobi, Kenya. 1p. [Information leaflet] [Field]	Information leaflet
NJUGUNA, J., MIANO, D., NJIHIA, S. and others (2003) Participatory farmer planning day for on-farm trials. Waruhiu FTC, Kiambu District, Kenya. 5th February 2003. [c. 60 participants including 40 farmers, 11 male] [Swahili and Kikuyu]	Farmer planning day including optional field visit to experimental plots
NJUGUNA, J.G.M., NJOROGE, P.G. AND JAMA, A.N. (2003). Epidemiology and maize crop resistance to head smut disease with reference to small- scale maize-dairy farmers in Central Kenya. Proceedings of the 2003 Crop Science & Technology Conference, Glasgow, 2: 999-1004. The British Crop Protection Council, Alton, Hampshire.	Paper in edited proceedings: (editors' names not usually included in citation)

NJUGUNA, J.G.M., NJOROGE, P.G., JAMA, A.N. and MURDOCH, A.J. (2003). Epidemiology and maize crop resistance to head smut disease with reference to small- scale maize-dairy farmers in Central Kenya. Presented by Dr Njuguna in Poster Session, Crop Production and Protection in Tropical Crops, at Crop Science & Technology Conference, Glasgow, 10-12 November 2003, Poster 7F-3.	Poster display
NJUGUNA, J. and team. (2004) Extension training workshop on IPM of Maize Forage Dairying. Farmer Training Centre, Githunguri, Kenya. 27 January 2004. 5pp.	Workshop
NJUGUNA, J. and team. (2004) Farmer Field Day on IPM of Maize Forage Dairying. Farmer Training Centre, Githunguri, Kenya. 28 January 2004. [One-Day Farmer Field Day for c. 180 farmers] [Swahili and Kikuyu]	Farmer field day
NJUGUNA, J., DORWARD, P.T. and MURDOCH, A.J. (2004) Report on Extension training workshop on IPM of Maize Forage Dairying. Farmer Training Centre, Githunguri, Kenya. 27 January 2004. [One-Day Workshop for c. 24 officers] [English]	Internal report