CROP PROTECTION PROGRAMME

R7571 (ZA0376)

Management of Virus Diseases of Vegetable Crops in Kenya
FINAL TECHNICAL REPORT

01 March 2000 – 31 March 2003

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R7571, CROP PROTECTION PROGRAMME

Acronyms

AVRDC	Asian Vegetable Research and Development Centre
BtMV	*Beet mosaic virus*
BWYV	*Beet western yellows virus*
CABI-ARC	Centre of Applied Biosciences International – Africa Regional Centre
CaMV	*Cauliflower mosaic virus*
CPP	Crop Protection Programme
DAS	Double antibody sandwich
DBM	Diamond back moth
DFID	Department for International Development
ELISA	Enzyme Linked Immunosorbent Assay
HRI	Horticulture Research International
KARI	Kenyan Agricultural Research Institute
NRI	Natural Resources Institute
PRA	Participatory Rural Appraisal
PTA	Plate trapped antigen
PU	Peri-urban
SE	Socio-economist
TGM	*Brassica juncea* cv. Tendergreen Mustard (TGM)
TuMV	*Turnip mosaic virus*

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Executive Summary

The Department for International Development (DFID) funded this research project through the Crop Protection Programme (CPP). It was implemented through a collaborative effort between Horticulture Research International (HRI), UK, Kenyan Agricultural Research Institute (KARI), Kenya and Centre for Applied Biosciences International – Africa Regional Centre (CABI-ARC), Kenya.

Smallholder horticultural production is an important and expanding component of rural livelihoods in Kenya. Vegetable production provides employment and income for farmers, their families and employees in regions where unemployment levels are high. Pest and disease damage threatens the yield of crops and to prevent them, vegetable farmers' usual response is heavy and frequent application of pesticides. These are expensive and are often unsuccessful in protecting crops, especially against virus disease. Reliance on pesticides has led to increasing concern about residues in produce, operator safety, pesticide resistance and environmental damage. Few alternatives are currently in use.

The project arose as a result of concern expressed by KARI, CABI-ARC and the peri-urban (PU) PSL that virus diseases were not being adequately addressed by the on-going PU vegetable project cluster which focuses on insect pests and nematodes. A short programme development study in February 1999 confirmed high levels of virus in cabbage, cauliflower and kale crops but the impact of these viruses on crop yield was unknown. The overall aim of the project was to develop improved methods for the control of virus diseases, in particular *Cauliflower mosaic virus* (CaMV) and *Turnip mosaic virus* (TuMV), in brassica crops in the PU vegetable systems being studied within the PU vegetable project cluster in Kenya.

The project developed recommendations for improved control of virus diseases in several key areas:

- The use of existing brassica varieties to best effect by screening land races of cabbage and kale for virus resistance.
- The use of simple, low-input methods to control aphids (which are often unnoticed or not attributed as the causal organism of virus disease by farmers).
- Development of an understanding of virus diseases and the control strategies available within the socio-economic context of peri-urban farming systems.

- Characterisation of TuMV and CaMV isolates in Kenya to identify amount of variability present in natural populations.
- Discussion of all research work with farmers and other stakeholders so that farmer needs could be addressed throughout the project.
- Consideration has been given to how virus disease management could be integrated with pest management.
- Two concept notes have been submitted to CPP: one takes forward on-farm seed multiplication and improvement of seed quality in Kenya (CN802). The other (CN801) promotes sustainable approaches to nematode and virus control.

Background

Recent population explosions in towns and cities are major phenomena of the last three decades in developing countries. This increase in the urban population presents a major challenge to the agricultural production sector of these countries to provide an adequate food supply to this growing urban centre. However, it also provides a major opportunity for small-scale farmers to supply fresh food to towns, which can be an extremely lucrative market. The small vegetable producing farms that surround Nairobi, while covering no more than 40,000 ha of smallholdings, provide a living for 150,000 people who produce food for the towns and also vegetables for export. Production of fresh vegetables for towns is one of the few ways in which very small farms can remain economically viable.

The intensive farming techniques used by smallholder farmers generate very high incomes but unfortunately these practices are threatening the sustainability of such farms because it is an ideal environment in which diseases and pests can thrive and build up to very high levels. This problem has arisen in vegetable producing regions of Kenya where there is a high incidence of virus diseases and insect pests. Insect pests, some of which can be vectors of virus, are showing such high levels of resistance to chemical insecticides that both the total productivity and the profitability of vegetable farming is affected. The frequent use of chemicals is also increasing environmental pollution and poses an increasing hazard to the workers, who must spray or handle the crops, as well as final consumers.

Virus diseases cause symptoms in crop plants that severely affect quality and reduce yield. There are many reports of field studies designed to determine yield losses caused by virus diseases. Examples are a 36% yield reduction caused by TuMV in cabbage (Walkey & Webb, 1978); 24-75% yield reduction in cassava in Kenya (Seif, 1982) and 25-60% yield reduction in maize caused by maize streak virus in Kenya (Guthrie, 1978). Virus diseases are known to affect important vegetable crops in Kenya and previous work by HRI, KARI and the Natural Resources Institute (NRI) revealed that TuMV and CaMV viruses infect Kale. However, there is currently no information on the impact of virus diseases in the cluster of projects on Integrated Pest Management in vegetable crops in Kenya.

This project arose from concern expressed by the PU-PSL, KARI and CABI that virus diseases were not being adequately addressed by the on-going PU vegetable project cluster which focuses on insect pests and nematodes. The need for a project to address virus diseases

was upheld by a survey of virus diseases in vegetable production on farms around Nairobi, supported by DFID Crop Protection Programme (CPP) (Spence, 1999 (Appendix 1)). The survey provided more information about the distribution and relative importance of viruses and found that cabbage, cauliflower and kale crops were virtually 100% infected with combinations of TuMV, CaMV and *Beet western yellows virus* (BWYV). Although there is no data for the economic significance of these viruses in Kenya, crop losses may be considerable because virus infection causes stunting of plants and reduced leaf area (kale) or head production (cabbage). However, in some crops there were reasonable yields despite extensive virus infection. This could be due to the time at which the crop became infected with virus where later infections probably have less impact on yield. All three viruses infecting these *Brassica oleracea* crops (cabbage and kale) are transmitted by several aphid species and are not transmitted in seed, however from observations and previous experience BWYV is not considered to be causing significant symptoms or losses. KARI identified the assessment of the economic significance of viruses in kale and cabbage as a research priority.

The non-persistent mode of transmission for TuMV means that it is very difficult to control using insecticides because brief probes by aphids are enough to cause virus infection. There may be more success in the control of CaMV as this is transmitted in a persistent manner, which means that aphids have to probe for longer to allow transmission of virus therefore allowing more time for the chemical control to take effect. Plant resistance is a more environmentally friendly method of controlling virus and is likely to be more effective than chemical control. Although no monogenic resistance has been identified in *B. oleracea* there are quantitative differences in resistance and it was noted that in Kenya there was some phenotypic variation in local cultivars of kale and differences in susceptibility to viruses in the field. Such cultivars are probably land races and some interesting sources of resistance could be present. Furthermore, partial resistance in these land races may be preferable to immunity because with monogenic resistance there is strong selection pressure for matching virulence genes in the pathogen. Seed was collected from land races of kale from the Kinale region, an area where farmers save and sell seed for planting. As there is evidence of differences in virus susceptibility of these land races in the field, seed should be screened for virus resistance and the potential for self-selection of seed by farmers to reduce incidence of diseases investigated. For evaluation of genetic resistance in land races of kale it will also be necessary to determine pathotype variability. This is currently possible for TuMV as differential cultivars and monoclonal antibodies are available at HRI. There is no system for

determining the pathotype of CaMV isolates, but local *Brassica* lines could be screened to examine CaMV variation. Isolates of CaMV and TuMV collected in the survey have been preserved for future use in these proposed studies.

In Kenya most brassica crops observed were initially grown in seed-beds where seed is densely sown. Seedlings are transplanted from seed-beds directly into the field. High levels of virus infection (10-50%) were observed in the seed-beds, although it is not known if this influences the subsequent level of virus infection developing in the transplanted crop.

In the survey it was also noted that pepper crops were 100% infected with combinations of pepper mild mottle virus and potyviruses, although as up to 10 different potyviruses can infect pepper further identification work is required. Cucumber and spinach crops were also severely affected by potyviruses, thought to be *Watermelon mosaic potyvirus 2* (WMV-2) and *Beet mosaic potyvirus* (BtMV) respectively. Spinach is an important leafy vegetable crop and further research on the economic significance of viruses in spinach may also be appropriate. Other crops that were virus infected included celery, pumpkin and lettuce. The viruses of importance in these vegetable crops are aphid-transmitted but not seed-transmitted and the key to their control is the use of resistant cultivars and management of the aphid vector. With such a wide range of crops with possible economically significant diseases it is necessary to prioritise research requirements, therefore the proposed research focuses on *Brassica* crops, with the possiblility of some work on spinach at a later time.

Project Purpose

As defined in the Project Memorandum the Project Purpose was to develop improved methods for the control of virus diseases, in particular CaMV and TuMV in brassica crops in the peri-urban (PU) vegetable systems being studied within the PU vegetable cluster in Kenya.

The project aimed to achieve virus control through:

- identification of virus-resistant germplasm
- cultural control methods to reduce virus incidence and spread
- improved vector control.

The project will have contributed directly to the achievement of the PU output 101: *"Improved methods for controlling weeds, insect pests, diseases and nematodes in market gardening and horticultural enterprises developed and promoted" and purpose for Kenya, a DFID target country."*

Research Activities

Research Activity 1.1 Stakeholder workshop to finalise the work plan and ensure co-ownership of the project.

Several institutes, CABI, HRI, KARI and NRI were collaborators in this project. To target activities for maximum impact a workshop was held to facilitate co-ordination activities and "face-to-face" brainstorming.

The objectives of the workshop were:

- To introduce project stakeholders to each other and encourage co-ownership of the project.
- To systematically discuss each of the project activities in detail and finalise i) what should be done, ii) how it should be done and iii) who should do it. As this project is part of a PU cluster it was also important to establish how the project activities could complemet the other projects.
- Some project stakeholders visited Nyathona to observe virus diseases of *Brassica* and spinach and to start survey and collection of virus infected samples.

Research Activity 1.2 Survey, collection and identification of virus isolates from brassica and spinach crops on peri-urban vegetable farms.

Brassica oleracea samples were collected and characterised during a survey of virus diseases in vegetable production in 1999 (Spence, 1999 (Appendix 1)). These isolates were stored only in the UK. As Kenyan quaratine regulations do not allow re-importation of viruses another 263 *B. oleracea* and *Spinacia oleracea* samples were collected from farms in the PU regions of Nairobi during this project. Samples were identified and stored at HRI, UK and at CABI/KARI, Kenya.

Characterisation of samples

After samples were collected they were characterised and stored for use later in the project. Each sample was divided into two, one part was kept at CABI/KARI, Kenya and the other was kept at HRI, UK.

At KARI/CABI the sample was further divided. One part was stored at –20°C, another ground and mechanically inoculated (Appendix 2) to susceptible plants and the other part ground for TuMV and CaMV ELISA tests (Appendix 2).

At HRI the sample was divided, one part was ground in inoculation buffer and stored in liquid nitrogen. The other part was mechanically inoculated (Appendix 2) to a universally susceptible host, *Brassica juncea* cv. Tendergreen (TGM). Symptoms were observed and recorded for three weeks. After three weeks, each sample was tested for the presence of TuMV and CaMV using ELISA (Appendix 2). Some samples were tested by electron microscopy (EM) to confirm ELISA test results. If the symptoms seen in TGM were good, an infected leaf was ground and diluted in inoculation buffer and stored in liquid nitrogen because success of revival from liquid nitrogen was previously found to be more successful from TGM than from field samples (S. Muthumeenakshi, personal communication).

BtMV was previously isolated from swiss chard in Kenya. Swiss chard samples collected during the project were mechanically inoculated (Appendix 2) to *Spinacia oleracea*. Once symptoms developed, infected leaves were ground in inoculation buffer and the samples were stored in liquid nitrogen. For identification purposes the samples were mechanically inoculated to a range of indicator plants (*Nicotiana tabacum, N. benthamiana, N. glutinosa, Chenopodium quinoa*, TGM). Once symptoms appeared, the samples were tested for the presence of a potyvirus using ELISA (Appendix 2) and the potyvirus identified using PCR (Appendix 2). Samples were sent to Dr Willi Metzger, SequiServe for sequencing. BLAST through the NCBI database and DNAStar were used to compare the sample sequence with other known sequences.

Research Activity 1.3 Screenhouse experiment to determine the effect of virus on yield in cabbage crops

Screenhouses were purpose built for research activities 1.3, 1.4 and 1.5 (Fig 1.3.1).

Cabbage cultivar Gloria was chosen for this experiment in October 2000 because it was identified as the most commonly grown cabbage cultivar (Oruko & Ndun'gu, 1999). There were four treatments: TuMV only, CaMV only, TuMV & CaMV combined and inoculation buffer (control). Twelve two-week old seedlings were mechanically inoculated (Appendix 2) per treatment. Isolates 89 (TuMV) and 24 (CaMV) were used (Appendix 3). Once plants began to show symptoms, typically two weeks after inoculation, they were assessed for presence or absence of TuMV and CaMV using TuMV-PTA ELISA and CaMV-DAS ELISA respectively (Appendix 2). If ELISA results were as expected the

Figure 1.3.1 Construction of screenhouses at Thika, NARL

plants were planted out in the design shown in Figure 1.3.2 (Figure 1.3.3). The plants were assessed every two weeks for disease symptoms.

The first attempt at this experiment was destroyed by black rot. The screenhouses were successfully sterilised by wetting and heat solarization (S. Roberts, HRI, personal communication) and the experiment repeated in September 2001. Cabbage cultivar Sugarloaf was used rather than Gloria F1 because Gloria F1 was susceptible to black rot. Sugarloaf was also chosen because virus disease symptoms were easy to identify. Unfortunately the second attempt was not successful due to mixed virus infections in seedlings raised at KARI-NARL. Vector proofing was found to be inadequate in the glasshouses and repairs were carried out.

The third attempt, in December 2001, was successful. There were four treatments as before and 12 two-week old Sugarloaf seedlings were mechanically inoculated per treatment. TuMV isolate 249 and CaMV isolate 189 were used (Appendix 3). Once plants began to show symptoms they were assessed for presence/absence of TuMV and CaMV using TuMV- and CaMV- PTA ELISA. The plants were planted into the screenhouse in the design shown in Figure 1.3.2 and were assessed every two weeks for disease symptoms as before.

Ten weeks after transplanting the cabbages were harvested, weighed using hand-held scales and assessed as marketable (firm heads) or unmarketable (not firm or de-formed heads or severe virus symptoms). The data was then statistically analysed.

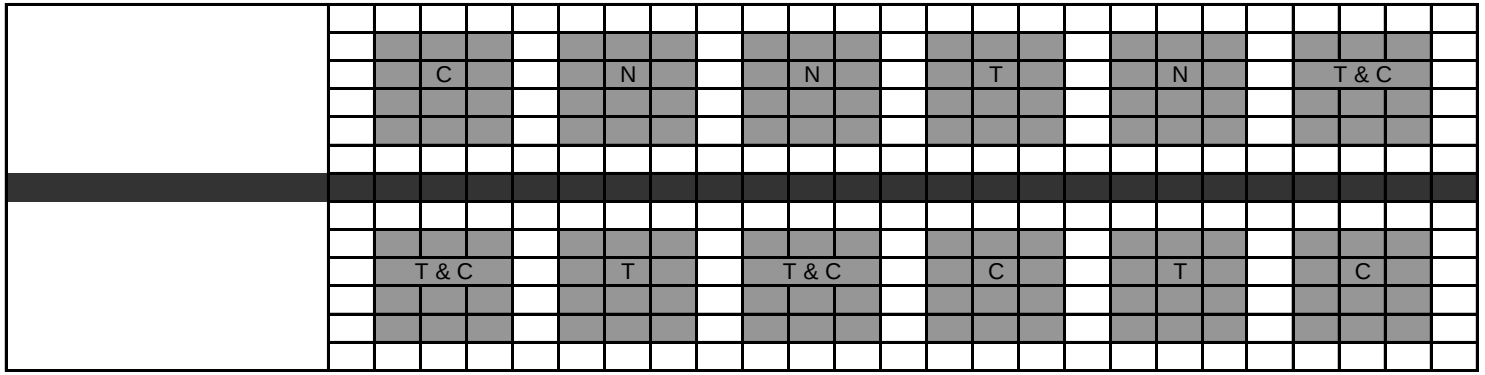
Research Activity 1.4 Screenhouse experiments to determine effect of the timing of virus infection

In the project memorandum the activity described was to asssess the impact of different timings of infection by TuMV and CaMV on yield of cabbage and kale. However, when the results of Activity 1.3 showed that CaMV did not have any effect on cabbage yield it was decided to investigate with just TuMV.

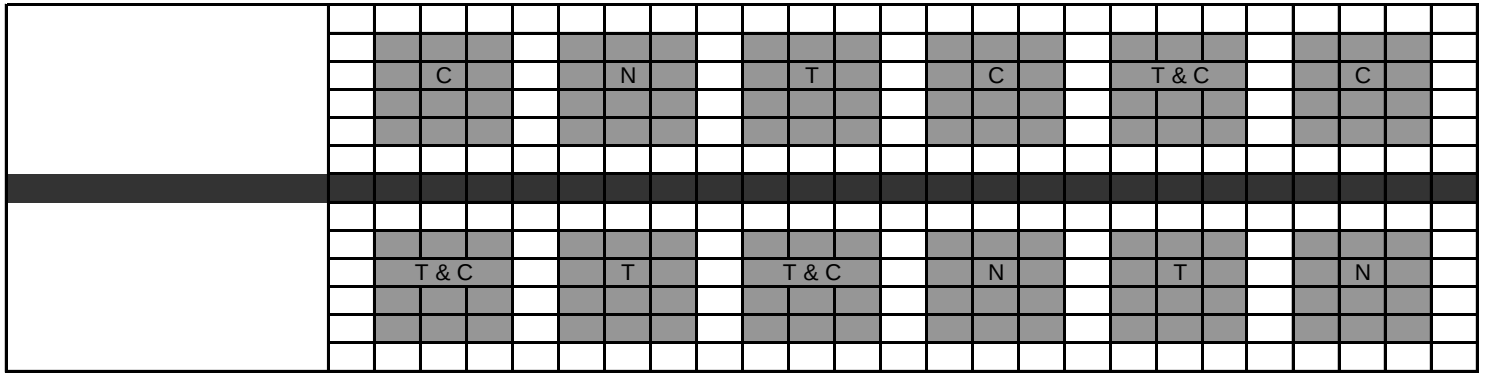
In April 2002 seedlings were mechanically inoculated (Appendix 2) with TuMV isolate 249; 12 seedlings were mechanically inoculated with inoculation buffer. After two weeks the seedlings were tested for the presence of TuMV using TuMV-PTA ELISA (Appendix 2).

Figure 1.3.2 Design of screenhouse experiment to assess the impact of TuMV & CaMV) both singly and in combination on the yield of cabbage

House 1



House 2



Where C = CaMV, T = TuMV, T & C = TuMV & CaMV, N = None

Figure 1.3.2 Planting of screenhouse trial

Plants that were positive were planted in the design shown in Figure 1.4.1 in position 2. Buffer inoculated plants were planted in position 1.

Uninoculated plants, the same age as those in positions 1 and 2 were planted in position 3. Four weeks after the initial inoculation plants in position 3 were mechanically inoculated with TuMV isolate 249.

Four weeks after transplanting (two weeks after the second inoculation) the plants were assessed every two weeks for virus symptoms. At maturity (11 weeks after transplanting) the cabbages were harvested, assessed as marketable (good head formation) or non-marketable (de-formed heads) and weighed using a hand-held scale. The data was then statistically analysed.

This experiment is currently being repeated to get data for more then one season and the effect of timing of TuMV infection on yield of kale is also being assessed (season 2). The design of the kale experiment is shown in Figure 1.4.2.

Research Activity 1.5 Screenhouse experiment to determine the effect of BtMV on the yield of spinach

During visits to farms it was noted that swiss chard is more widely grown than spinach therefore this activity was modified to assess effect of BtMV on swiss chard. In addition, a timing element was included to gain more information about the nature of BtMV infection at different levels of maturity.

In May 2002, 200 seedlings were mechanically inoculated with inoculation buffer (treatment 1) and 200 were mechanically inoculated with BtMV isolate S8 (treatment 2). Two weeks after inoculation the seedlings were tested for presence of BtMV using the Potyvirus PTA-ELISA test (Appendix 2). Treatment 1 plants, which were all ELISA negative, were planted in positions 1; treatment 2 plants that were positive were planted in positions 2 (Figure 1.5.1). Uninoculated plants the same age as those in positions 1 and 2 were planted in positions 3. Four weeks after the initial inoculations plants in position 3 were mechanically inoculated with BtMV isolate S8.

Figure 1.4.1 Design of screenhouse experiment to assess impact of timing of Turnip mosaic virus (TuMV) infection on cabbage yield. 1, control (buffer inoculated); 2, first TuMV inoculation; 3, second TuMV inoculation.

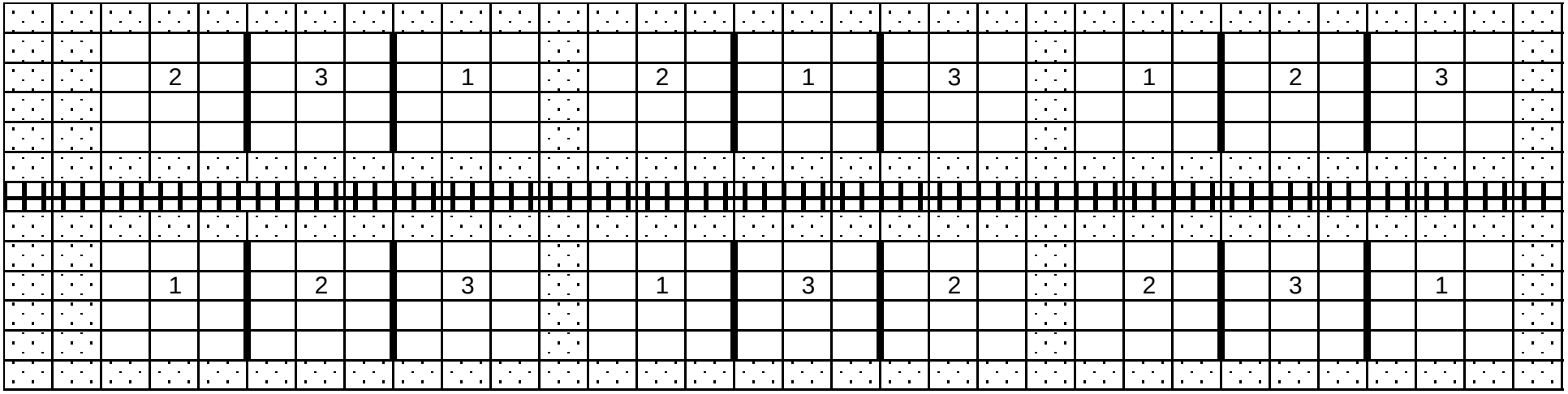


Figure 1.4.2 Design of screenhouse experiment to assess the effect of timing of Turnip mosaic virus (TuMV) infection on yield of kale

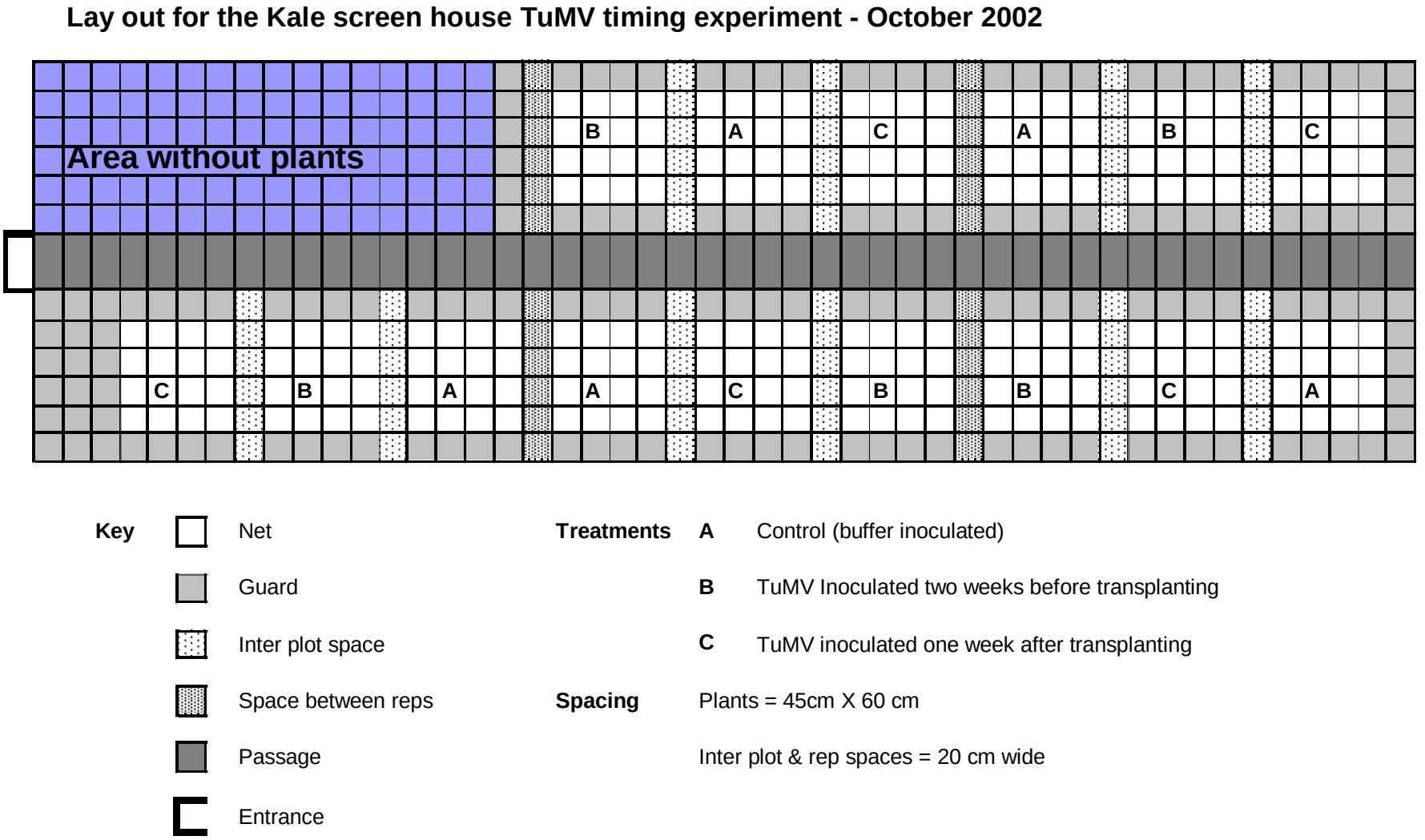
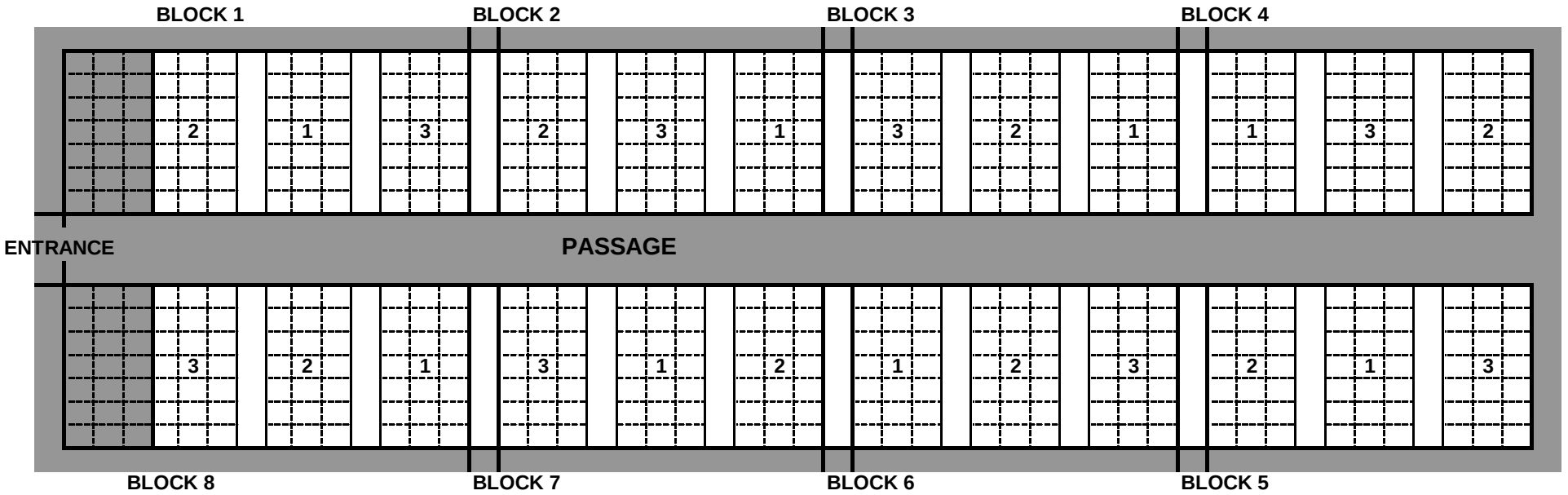


Figure 1.5.1 Design of screenhouse experiment to assess the effect of timing of Beet mosaic virus infection on the yield of swiss chard



1 = Inoculated with buffer
2 = BtMV inoculation 1
3 = BtMV inoculation 2

PLOT DETAILS
Net plot size = 3 rows X 7 plants (0.9 m X2.8 m)
Plant spacing = 30 cm X 40 cm
Interplot spacing = 60 cm
Inter block spacing = 80 cm
A guard row was put at each end of the plot, and at both ends of the trial.
Guard rows were also put towards the entrance

Two weeks after the second inoculation plants were assessed for symptoms using the assessment sheet shown in Figure 1.5.2. Assessments continued once fortnightly for 16 weeks, after which they were harvested and weighed. The data was then analysed using Genstat

Research Activity 2.1 To investigate methods to protect Brassica seed beds from virus infection

As described in the project memorandum these activities investigated the spread of viruses from seed-beds into the transplanted crop and the potential of alternative management strategies to reduce the incidence of virus disease in brassica crops.

The effect of two alternative, low input treatments, synthetic, re-usable fleece and straw mulch were compared with an untreated control. The fleece provided a physical barrier to the aphids and so the crop from this treatment was exposed to any infestation only after transplanting, whereas the straw and control were open to infestation by aphids and infection by virus diseases at all times.

Two experimental sites were used – KARI, Thika and University of Nairobi, Kabete Campus. Experiments were carried out in a Randomised Complete Block Design (RCBD). In the first season (November 2000) the nurseries had treatments laid out in three blocks and in the second season (June 2001) they were in six blocks. In the field, the crops from the three treatments in the nurseries were randomised within six blocks and a total number of 18 plots. In the second season, an additional treatment of straw mulch was added to field plots from straw mulch nurseries therefore increasing the number of treatments to four and the total number of plots to 24.

Cabbage (*Brassica oleracea*) variety Gloria F1 was used and seeds were purchased from Simlaw Seed Company, Kenya. The seeds were sown at Kabete and Thika in 2m by 1m nursery beds. Broad-spectrum fungicide, Monceren T Pencyron + Thiram ($4g.l^{-1}$) was applied to the nursery beds at sowing, to protect against soil borne pathogens *e.g. Fusarium* spp. Farmyard manure and di-ammonium phosphate (DAP) fertiliser were used to supply nutrients to the soil in the beds. Daily watering and weeding were carried out until tansplanting, when the crop was 4 weeks old.

Figure 1.5.2 Assessment sheets for swiss chard experiment

BtMV SWISS CHARD SCREEN HOUSE EXPERIMENT - DATA SHEET

Date_____ Recorder_____

Block_____ Treatment_____

Plant number	Symptoms	Severity	Remarks
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			

Symptoms

Chlorosis = 1

Vein Clearing = 2
Leaf distortion = 3
Mottling = 4
Mosaic = 5

Puckering = 6

Stunting = 7

Severity

0 = none

1 = symptoms 1,2,3, and 4
2 = symptoms 1,2,3,4, and 5 + slight distortion of leaves
3 = symtoms 1,2,3,4,5,6 + stunting

The crop was tansplanted in 3.6m by 3.6m plots. Each plot had 49 plants, with 60cm between and within the rows. DAP was applied to the planting holes and mixed well with soil before introducing the seedling. The crops were irrigated by hand because most part of the seasons were dry. Diamond back moth (*Plutella xylostela*) was controlled with the use of Thuricide ®, a biopesticide with no effect on aphids.

Data collection started at the nursery level and continued into the field after transplanting until harvest. The aphid scoring system used was modified from Sutherland *et al*. (1996). The aphids were scored on a randomly picked leaf from each plant and a scale of 0-3 was used. A leaf score of 0 had no aphids, 1 had no more than two colonies, 2 had up to 50% leaf coverage and 3 had more than 50% surface covered by aphids. The virus severity scale 0-3 was modified from Sutherland *et al*. (1996). A score of 0 was a healthy plant, 1 mottling and vein clearing, 2 mottling, vein clearing, mosaic and slight distortion, 3 mottling, vein clearing, mosaic, severe distortion and stunting. Virus incidence was recorded as either positive or negative. Data collection was carried out on a weekly basis.

Harvesting of the heads was done when the cabbage heads were hard and firm. The heads were cut and the weight for each recorded. The cabbage heads were classified as either marketable or non-marketable.

Analysis of variance was used to compare the differences of aphid scores and virus incidences in the different treatments. Correlation analysis was carried out to determine the relationships between aphids and virus incidences.

Research Activity 2.2 To determine any quantitative effects of reducing virus infection in Brassica seedbeds on the levels of virus disease in the transplanted crop

The activity described in the project memorandum was to use an unpublished model (Jeger, personal communication) to obtain quantitative data on vector dynamics, behaviour and transmission characteristics. To do this it was necessary to obtain information on viruliferous aphids collected in the field. Attempts at PCR amplification of virus from aphids was unsuccessful. The virus is unstable at high temperatures. The aphids were collected in the field under high temperature conditions and this may have caused the virus to degrade, making

detection difficult. Therefore extra information on other pests and diseases were collected and included in the analysis of activity 2.1.

Research Activity 2.3 Evaluation of farmer acceptability of alternative control strategies

PRA activities were used to evaluate farmer acceptability of low input control strategies used in activities 2.1 and 2.2.

More detailed descriptions of activities are in Njuki, 2002 Appendix 4.

2.3.1 Initial PRA activity

The aims of the PRA were to:

- Identify constraints on improved control measures such as costs and practicability
- Gauge farmers' willingness to participate in on-farm trials

Two sites were selected, Ruiru and Athi River, for on-farm trials. Focus group discussions with farmers were held at these two sites, a checklist was used to guide the discussions. A wealth ranking exercise was also included to classify farmers into different social categories for the evaluation of the control methods.

2.3.2 Participatory budgeting [#]

The feasibility, implications and sustainability of the disease control strategies were evaluated using the participatory budgeting technique. The budgets are simple to follow, use local materials and also take into account non-cash resources, *e. g.* labour.

Two farmer groups were involved in the participatory budgeting process, Athi River and initially Ruiru. The Ruiru group did not complete the experiment due to internal group and leadership problems. The group was replaced with an organic group of farmers from Kariguini, who had earlier been involved in a project on the control of root knot nematode. Figure 2.3.1 shows a summary of which groups participated in which stages of the activity.

[#] methods developed by Peter Doward and Mark Galpin of the Department of Agriculture and Derek Shepherd, Head of AERDD in a DFID funded project

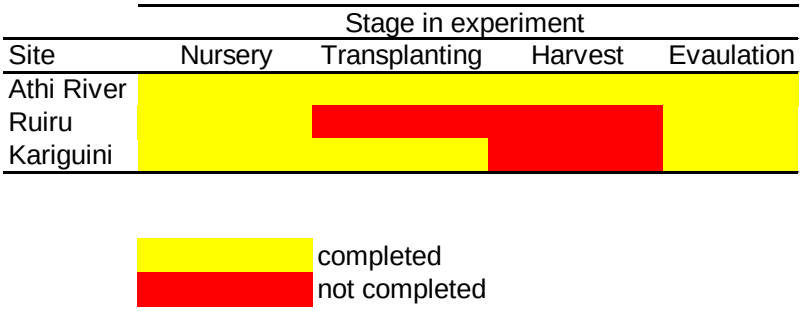


Figure 2.3.1 **A breakdown of the farmer groups that participated at different stages of Activity 2.3**

The aims of the participatory partial budgeting exercise were to:

- Evaluate the feasibility, implications and suitability of different viral disease management strategies
- Stimulate farmer interest and participation in the off farm trials by using the budgets as the farmer led research component in the on farm trials
- Stimulate discussion among farmers on viral diseases and the different control strategies.
- Assess demand for appropriate control technologies.

Originally three treatments were to be evaluated however when discussions were held with farmers they suggested a fourth treatment that they already used in the field. Hence four treatments were evaluated at the nursery level: fleece, straw mulch, a farmer practice treatment (dimethoate) and a control (no treatment). Eight treatments were evaluated at the field level because each of the nursery treatments were divided into two in the field: fleece, straw mulch and control were divided into mulch and no mulch while the dimethoate treatment was divided into mulch and dimethoate.

The farmers in Athi River were literate therefore farmers participated extensively in recording activities on flipcharts. In Kariguini, most of the farmers were literate but for the benefit of those who were not, dramatisation or the use of physical objects were used to demonstrate the various aspects of the experiments.

An inputs data sheet was developed and farmers were trained how to use the sheet and do basic record keeping as part of their own farm management. The data was collected on-site at the

completion of each day's activities. The SE did the first recording of inputs, subsequent activities and inputs were recorded by farmers under the guidance of a team member.

Phase one of the partial budget

One month after initiating the trial the experiment was reviewed to ensure farmers still understood the purpose of the experiment. Inputs common to all treatments and those that would not be used in a real farm situation were removed for the second phase of the partial budget. The input lists were transferred to the budget sheet and the quantities added up for each input to make a quantities table. The inputs were priced as follows:

- Farm labour: Ksh 100 for a 5 hour day.
- Dimethoate and polythene bags: local market price.
- Fleece: not available locally so the UK price was used.
- The costs were then added up for each treatment.

Phase two of the partial budget

The inputs, outputs and extra costs were quantified. The methodologies for participatory partial budgets require comparisons of treatments with each other however this was confusing to the farmers hence the treatments were only compared to the control.

Statistical analysis of the yield data

The data of the gross plot prices was analysed using Analysis of Variance in Genstat (Genstat 4.2, 2000, Appendix 4). The budget was converted into a per hectare basis so that it would be more logical to farmers (Appendix 4). It was necessary to statistically analyse the farmers results because there was no consistency in the evaluation of results *e.g.* a 2kg cabbage was priced at Ksh 10 whereas a 4kg cabbage was priced at Ksh 15 and this requirement was explained to farmers.

Kariguini was unable to complete the experiment due to flooding of the experimental site therefore the results from Athi River were discussed with all three groups (Athi River, Kariguini and Ruiru) and were used for the evaluation of treatments.

Farmer discussions and evaluation of the control strategies

Due to the complexity of using all 8 treatments for the evaluation, farmers opted to evaluate the treatments broadly as mulch, fleece, dimethoate and control. Farmers selected criteria to

help them decide if a management strategy would be adopted: labour requirement, benefits, availability of materials, ability to control the disease and use of other inputs. The farmers ranked each treatment (best = 1, worst = 4) according to the criteria for adoption, discussed the advantages and disadvantages of each treatment and gave a final score for each treatment (total for all treatments = 100).

Research Activity 3.1 To determine pathotype variability of TuMV isolates

TuMV isolates identified in activity 1.2 were maintained by mechanical inoculation in TGM (Appendix 2). Five *B. napus* lines (Walsh, 1989; Jenner & Walsh, 1996; Hughes 2001) were used as differentials and were mechanically inoculated with isolates. Symptoms were observed and recorded over a period of four weeks. Results that were not clear were assessed by TuMV-PTA ELISA (Appendix 2).

Isolates were also evaluated using a panel of monoclonal antibodies (Jenner *et al*., 1999) in TuMV-PTA ELISA as described in Appendix 2 but with the following changes to the primary antibody:

EMA 58
EMA 67
EMA 70
EMA 84
EMA 115

Isolates were then classified into a serotypic group depending on their interaction with each of the antibodies.

Attempt at CaMV classification

Five monoclonal antibodies were produced at HRI (Table 3.1.1) and used in CaMV PTA-ELISA. Background levels were very high making the identification of positive results difficult. A blocking step was incorporated which reduced background results to approximately 0 OD. Three isolates were tested for preliminary classification with the five monoclonal antibodies.

Table 3.1.1 Table of CaMV monoclonal antibodies produced at HRI and their isotype

Antibody	Isotype
EMA 195	IgG3
EMA 196	IgM
EMA 199	IgG2a
EMA 200	IgG2b
EMA 201	IgM

Research Activity 3.2 Evaluate local cultivars of cabbage and kale for resistance to TuMV and CaMV and a local cultivar of swiss chard for resistance to BtMV

TuMV inoculations

Seed lots collected in the previous 1999 survey were planted in M2 compost in FP9 pots at HRI, UK. At the two leaf stage plants were mechanically inoculated (Appendix 2) with a TuMV isolate (472/170, Appendix 3) and assessed weekly over a period of four weeks. After four weeks, plants that had none or had questionable symptoms were assessed using TuMV PTA ELISA (Appendix 2). Those that were classed as resistant were inoculated again with the same isolate and assessed for a further three weeks. If they remained symptomless they were transplanted into bigger pots and were vernalised at 4°C for 12 weeks. After 12 weeks they were put in the glasshouse at 18°C. Once the plants flowered they were bagged with plastic "bread bags" and allowed to set seed. Occasionally the plants would be shaken to encourage transfer of pollen.

CaMV inoculations

Seed lots collected in the previous 1999 survey were planted in M2 in FP9 pots. At the two leaf stage plants were mechanically inoculated with a CaMV isolate (472/25, Appendix 3) and assessed over a period of six weeks (because CaMV symptoms take longer to become apparent than TuMV symptoms). After six weeks plants that remained symptomless or were questionable were assessed by CaMV PTA-ELISA (described in Appendix 2). Those that were classed as resistant were inoculated again with the same isolate and were assessed for another 4 weeks.

BtMV inoculations

As for TuMV inoculations but BtMV isolate 472/117 (Appendix 3) was used to mechanically inoculate swiss chard. Plants were assessed for resistance using universal potyvirus PTA-ELISA (Appendix 2).

Research Activity 3.3 Screen promising cultivars and land races

Sixteen seed lots were collected from Kinale in the peri urban area of Nairobi, and together with one previously selected landrace, and a commercial variety of Kale were evaluated in a Randomised Complete Block Design (RCBD) with four replicates at Kenya Agriculture Research Institute Thika and National Agriculture Research Laboratories (NARL). The

plants were planted at spacing of 45 cm by 60 cm in the field. The plot sizes were 6 plants by 6 plants (gross), and 4 plants by 4 plants net.

Pest and yield data were collected at fortinightly intervals. Plants expressing resistance/tolerance to viral diseases and insect pests were tagged, and seed collected.

Research Activity 3.4 To determine the potential of self-selection of seed

The purpose of this activity was to assess the potential of seed from resistant/tolerant varieties as a strategy for virus disease management. An initial PRA was carried out to gain baseline information on farmer perceptions and practices (Appendix 5). This activity was also linked with PRA activity 4.

Farmers save their own kale seed in Kinale. Nine farms were selected in the Kinale area:

Simon Njugia	John M Ngugi	John W Kimani
Robert Ngirishe	James Njoroge Nene	Peter Njuguna
Benard Mbeki	Rachael Nyoro	Jacinta Ngugi
Josephine Wangari	Gertrude Njoki	Loise Wanjiru
Tabitha Muthoni	Jane Njeri	Josephine Wambui
Lucy Wambuku	Grace Wambui	George Kan'goroti

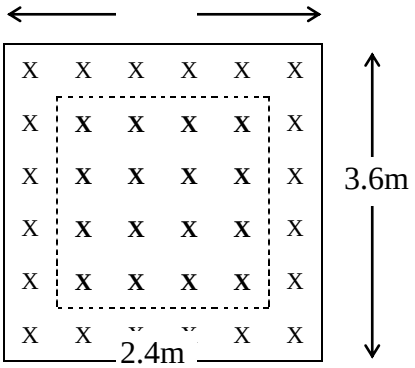
Researchers identified and tagged both healthy and diseased plants for seed. To link these with farmer participation the nine farmers were asked to identify plants they would consider suitable as planting material (good) and plants they would consider unsuitable (bad) which were subsequently tagged for seed. During the tagging process farmers were also shown how to identify the viral symptoms.

When the seed were harvested, seed from each individual plant was kept separately. For the on-station experiments seed from four farms was selected at random. Seed from individual plants were planted into plots (Figure 3.4.1). Researchers assessed the plots for presence of pests and diseases using assessment sheets in Figure 3.4.2.

On-farm seed from plants from each category were grouped and then planted into different categories: farmer good, farmer bad, scientist good and scientist bad (Figure 3.4.3). Farmers

Figure 3.4.1 Field Design for On-Station Farmer Seed Selection Trial

Plot design in the field (inter-row spacing = 0.6m, intra-row spacing = 0.6m)



Gross Plot = 6 rows x 6 plants (3.6x3.6m) = 36plants

Net Plot = 4 rows x 4 plants (2.4x2.4m) = 16plants

Block 4

T9	**T6**	**T2**	**T16**	**T15**	**T17**	**T8**	**T1**	**T14**
T12	**T13**	**T3**	**T7**	**T11**	**T18**	**T4**	**T5**	**T10**

Block 3

T2	**T14**	**T16**	**T7**	**T8**	**T12**	**T13**	**T3**	**T15**
T5	**T1**	**T18**	**T17**	**T10**	**T9**	**T6**	**T11**	**T4**

Block 2

T4	**T12**	**T3**	**T6**	**T18**	**T15**	**T9**	**T13**	**T11**
T1	**T8**	**T17**	**T5**	**T2**	**T7**	**T16**	**T14**	**T10**

Block 1

T7	**T16**	**T5**	**T14**	**T12**	**T6**	**T3**	**T15**	**T17**
T9	**T11**	**T1**	**T4**	**T13**	**T10**	**T18**	**T8**	**T2**

Key

Treatment	Description	Treatment	Description
T1	Farm 1, healthy plant 1	T10	Farm 3, healthy plant 2
T2	Farm 1, healthy plant 2	T11	Farm 3, diseased plant 1
T3	Farm 1, diseased plant 1	T12	Farm 3, diseased plant 2
T4	Farm 1, diseased plant 2	T13	Farm 4, healthy plant 1
T5	Farm 2, healthy plant 1	T14	Farm 4, healthy plant 2
T6	Farm 2, healthy plant 2	T15	Farm 4, diseased plant 1
T7	Farm 2, diseased plant 1	T16	Farm 4, diseased plant 2
T8	Farm 2, diseased plant 2	T17	Collards (commercial)
T9	Farm 3, healthy plant 1	T18	Thousand headed (commercial)

Figure 3.4.2 Assessment sheets for on-farm trials of potential of self seed selection

BLOCK_____ TREATMENT_____ DATE_____ RECORDER_____WK___

Plant no	Aphid score			Other insects				Diseases				Remarks
	***Brevicoryn* spp.**	***Myzus* spp.**	***Lipaphis* spp.**	**DBM**	**Thrips**	**Whiteflies**	***Macrosiph um* spp.**	**Virus**	**Downy mildew**	**Black rot**	**Powdery mildew**	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Figure 3.4.3 Design of on-farm self-selection of seed experiments at Kinale

1. **FARMER NAME:**_____

1. SH:	**2. FG**	**3. SINF**	**4. FB**

2. **FARMER NAME:** _____

4.FB	**3. SINF**	**2.FG**	**1.SH**

3. **FARMER NAME:** _____

3.SINF	**1.SH**	**4.FB**	**2.FG**

4. **FARMER NAME:** _____

4.FB	**2.FG**	**3.SINF**	**1.SH**

5. **FARMER NAME:** _____

2.FG	**1.SH**	**4.FB**	**3.SINF**

6. **FARMER NAME:** _____

1.SH	**4.FB**	**2.FG**	**3.SINF**

7. **FARMER NAME:** _____

3.SINF	**2.FG**	**1.SH**	**4.FB**

8. **FARMER NAME:** _____

3.SINF	**4.FB**	**1.SH**	**2.FG**

9. **FARMER NAME:** _____

1.SH	**3.SINF**	**2.FG**	**4.FB**

TREATMENT DETAILS

TREATMENT	**TREATMENT DESCRIPTION**
1. SH	Non-diseased (selected by scientists)
2. FG	Farmer's good (selected by farmer)
3. SINF	Diseased (selected by scientists)
4. FB	Farmer bad (selected by farmer)

The seed bed size is 1m by 1m

were not informed which batch of seeds came from which category of tagged plants. Farmers evaluated the seed- beds for germination rates, colour and disease symptoms using the assessment sheets in Figure 3.4.4.

A farmer field day was held and 19 farmers attended it. A fact sheet was produced to help farmers understand the purpose of the trial (Appendix 8).

Research Activity 4.1 PRA to assess farmer problems, perceptions and practices in relation to virus diseases and their aphid vectors

The PRA was carried out at sites selected for Activity 2, Athi River and Ruiru, where farmers grow brassicas for both commercial and domestic use.

The aims of the PRA were to:

- Evaluate farmer perceptions of virus symptoms and relative importance compared to other production constraints
- Obtain local knowledge of virus diseases and any current control measures
- Evaluate perceptions of resistance/susceptibility of land races of kale and cabbage to virus symptoms
- Compare social and cultural variations in farmer perceptions and practices.

Focus group discussions with farmers were held at these two sites with a checklist to guide the discussions (Appendix 4). This activity was combined with Activity 2.3.

Figure 3.4.4 Farmers assessement sheets for evaluation of self-seed selection

Farm No ……..…
Name of farmer...…….
Procedure for evaluation

1. For each of the evaluation criteria, give a total score of 20.
2. Ask the farmer to give each of the treatments a score out of the 20 (To allocate the 20 scores to the 4 treatments.)
3. Ask the farmer to combine all the criteria and give a general score for each of these treatments (these scores must also add up to 20)

Treatment	**Treatment identity (not to disclose to farmer))**	**Germination time**	**% Germination**	**Colour**	**Height**	**Disease**	**Pest attack**	**General appearance**	**General score**
T1									
T2									
T3									
T4									
Total		20	20	20	20	20	20	20	20

Outputs

Research Activity 1.1 Stakeholder workshop to finalise the work plan and ensure co-ownership of the project.

A workshop was held, involving project stakeholders, to finalise the work plan and to ensure co-ownership of the project. The outcome of the workshop is summarised in the workshop report (Appendix 6).

Research Activity 1.2 Survey, collection and identification of virus isolates from brassica and spinach crops on peri-urban vegetable farms.

Appendices 3 and 7 show a summary of the farms visited for sample collection, the description of symptoms on sample plants, insects observed on plants and ELISA results. Table 1.2.1 shows the location of characterised samples in liquid nitrogen storage at HRI. Appendix 3 show results of ELISA tests to categorise samples into into either TuMV infected, CaMV infected or not infected. Some samples collected (specifically samples between 175 and 263) did not revive upon return to HRI, UK so were unable to be classified.

The swiss chard potyvirus produced similar reactions on indicator plants as *Beet mosaic virus* (BtMV) and *Carnation vein mottle virus* (CVMV). ELISA tests were not used to further resolve the identification of the potyvirus as antibodies to BtMV and CVMV were not available. Universal potyvirus PCR primers were used to amplify the coat protein of the unknown potyvirus which was then sequenced and compared to other sequences in the NCBI database (Figure 1.2.1). The unknown potyvirus coat protein was almost 100% coincidental with the sequences of two known BtMV coat protein sequences.

Discussion

Overall singular infections of TuMV and CaMV were found in roughly equal proportions (27% of samples collected each) whereas mixed infections were much less frequent (8% of samples collected) (Table 1.2.2). A high proportion of the samples collected from Athi River (60%) were infected with TuMV compared to 3% infected with CaMV and 22% infected with both viruses. Nyathona had a relatively high proportion of samples with CaMV (48%) and Kinale had the viruses in roughly equal proportions. These results suggest that TuMV and CaMV may inhabit different areas, e.g. Athi River is lowland and

Table 1.2.1 Sample locations in liquid nitrogen

Sample	Location	Sample	Location	Sample	Location	Sample	Location
1	GK1 6 H A1	34	GK1 6 H E4	94	GK1 6 G D4	155	GK4 1 A D7
2	GK1 6 H A2	36	GK1 6 H E6	96	GK1 6 E J10		GK4 1 A D8
3	GK1 6 H A3	37	GK1 6 H E7		GK1 6 G D6	156	GK4 1 A D10
4	GK1 6 H A4	38	GK1 6 H E8	98	GK1 6 G D8		GK1 6 G G8
5	GK1 6 H A5	39	GK1 6 H E9	99	GK1 6 G D9		GK1 6 G G10
6	GK1 6 H A6	40	GK1 6 F D4	100	GK1 6 G D10	157	GK1 6 H J5
7	GK1 6 H A7		GK1 6 F D5	106	GK4 1 A F5		GK4 1 A E2
8	GK1 6 H A8		GK1 6 F D6		GK4 1 A F6	158	GK4 1 A E3
9	GK1 6 F A1		GK1 6 H E10	107	GK4 1 A F7		GK4 1 A E4
	GK1 6 F A2	41	GK1 6 H F1		GK4 1 A F8	159	GK4 1 A E5
	GK1 6 F A3	42	GK1 6 H F2	108	GK4 1 A F9		GK4 1 A E6
	GK1 6 H A9	43	GK1 6 H F3		GK4 1 A F10	160	GK4 1 A E7
10	GK1 6 H A10	44	GK1 6 H F4	110	GK4 1 A G1		GK4 1 A E8
12	GK1 6 G F1	45	GK1 6 H F5		GK4 1 A G2	161	GK1 6 H J6
	GK1 6 G F3	46	GK1 6 H F6	115	GK4 1 A G3		GK4 1 A E9
13	GK1 6 F A4	47	GK1 6 H F7		GK4 1 A G4		GK4 1 A E10
	GK1 6 F A5	48	GK1 6 E J8	116	GK4 1 A G5	162	GK1 6 G H1
	GK1 6 F A6	49	GK1 6 H F9		GK4 1 A G6		GK1 6 G H3
15	GK1 6 F A8	51	GK1 6 G F9	117	GK4 1 A G7	163	GK4 1 A H4
	GK1 6 F A9		GK1 6 G G2	136	GK4 A 1 A2		GK1 6 G H5
16	GK1 6 H B6	52	GK1 6 H G2	137	GK4 1 A A4		GK1 6 G H7
17	GK1 6 H B7	54	GK1 6 H G4	138	GK4 1 A A5	164	GK4 1 A H5
18	GK1 6 E J9	56	GK1 6 H G6		GK4 1 A A6		GK4 1 A H6
	GK1 6 F B2	57	GK1 6 H G7	139	GK4 1 A A7	165	GK4 1 A H7
	GK1 6 F B3	58	GK1 6 H G8		GK4 1 A A8		GK4 1 A H8
19	GK1 6 H B9	59	GK1 6 H G9	141	GK4 1 A B1	166	GK4 1 A H9
20	GK1 6 H B10	60	GK1 6 H G10		GK4 1 A B2		GK4 1 A H10
22	GK1 6 H D2	61	GK1 6 G A1	142	GK4 1 A B3	167	GK4 1 A I1
23	GK1 6 E I1	62	GK1 6 G A2		GK4 1 A B4		GK4 1 A I2
	GK1 6 H D3	64	GK1 6 G A4	143	GK4 1 A B5	168	GK4 1 A I4
24	GK1 6 F B5	65	GK1 6 G A5		GK4 1 A B6	169	GK4 1 A I5
	GK1 6 F B6	67	GK1 6 G A7	144	GK4 1 A B7		GK4 1 A I6
25	GK1 6 F B7	69	GK4 1 A F1	145	GK1 6 H J3	170	GK4 1 A I9
	GK1 6 F B8		GK4 1 A F2		GK1 6 H J4		GK1 6 G H9
	GK1 6 F B9	70	GK1 6 G A10		GK4 1 A B10		GK1 6 G I2
	GK1 6 H J1	71	GK1 6 G B1	146	GK4 1 A C1	171	GK4 1 A J1
	GK1 6 H J2	72	GK1 6 G B2		GK4 1 A C2		GK4 1 A J2
26	GK1 6 F C1	73	GK1 6 G B3	147	GK4 1 A C3	172	GK4 1 A J3
	GK1 6 F C2	74	GK1 6 G B4		GK4 1 A C4		GK4 1 A J4
	GK1 6 F C3	75	GK1 6 G B5	148	GK4 1 A H1	173	GK4 1 A J5
	GK1 6 H D6	76	GK1 6 G B6		GK4 1 A H3	174	GK4 1 A J6
27	GK1 6 H D7	77	GK1 6 G B7		GK1 6 G G4	189	GK1 6 G E2
28	GK1 6 H D8	78	GK1 6 G B8		GK1 6 G G6	214	GK1 6 G E4
29	GK1 6 H D9	81	GK1 6 G C1	149	GK4 1 A C7	219	GK1 6 G E6
30	GK1 6 H D10	82	GK1 6 G C2		GK4 1 A C8		GK1 6 G E8
31	GK1 6 H E1	83	GK1 6 G C3	150	GK4 1 A C9	239	GK1 6 G I8
32	GK1 6 F C4	84	GK1 6 G C4		GK4 1 A C10		GK1 6 G I10
	GK1 6 F C5	85	GK1 6 G C5	151	GK4 1 A D1	244	GK1 6 G J1
	GK1 6 F C6	86	GK1 6 G C6		GK4 1 A D2		GK1 6 G J3
33	GK1 6 F C7	89	GK1 6 G C9	152	GK4 1 A G9	249	GK1 6 G J4
	GK1 6 F C8	90	GK1 6 G C10		GK4 1 A G10		GK1 6 G J5
	GK1 6 F C9	91	GK1 6 G D1	154	GK4 1 A D5	252	GK1 6 G I4
	GK1 6 H E3	92	GK1 6 G D2		GK4 1 A D6		GK1 6 G I6

```
BtMV : 31  tggtgtattgagaatggcacatcaccaaatctcagtggagactgggtcatgatggatgga 90
           ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||
Poty : 982  tggtgtattgagaatggcacatcaccaaatctcagtggagactgggtcatgatggatgga 1041

BtMV : 91   gaggaacaagtttcattccccttgaagccgatagtagaaaatgctaaaccatcttttcgg 150
           |||||||||||| |||||||||||||||||||| ||||||||||||||||||||||||||
Poty : 1042 gaggaacaagtctcattccccttgaagccgataatagaaaatgctaaaccatcttttcgg 1101

BtMV : 151  caaataatgcatcacttttctgatgcagcagaagcgtatattgaaatgcgcaacagagaa 210
           ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||
Poty : 1102 caaataatgcatcacttttctgatgcagcagaagcgtatattgaaatgcgcaacagagaa 1161

BtMV : 211  aggccatacatgcctcgttatggcgctcagagaaatctgagagacaggacgctagctcgc 270
           |||||||||||||||||||||||||||||||||||||||||||||| ||||||||||||
Poty : 1162 aggccatacatgcctcgttatggcgctcagagaaatctgagagacagaacgctagctcgc 1221

BtMV : 271  tatgcattcgatttctatgaggtcacctcacgaacaactgatcgtgcacgtgaagctcat 330
           ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||
Poty : 1222 tatgcattcgatttctatgaggtcacctcacgaacaactgatcgtgcacgtgaagctcat 1281

BtMV : 331  ttccaaatgaaggcggcagcgttggcaagcgtgtccaacaagctctttgggcttgatggg 390
           ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||
Poty : 1282 ttccaaatgaaggcggcagcgttggcaagcgtgtccaacaagctctttgggcttgatggg 1341

BtMV : 391  agcgtggccaccacatcggaggatacagagaggcacacagccacagatgttaacgctcac 450
           |||||||||||||||||||||||||||||||||||||||||||||||||| |||||||||
Poty : 1342 agcgtggccaccacatcggaggatacagagaggcacacagccacagatgtcaacgctcac 1401

BtMV : 451  atgcatcacatgatgggcgttcgacaaggttaattctgtacctcgttctatggatagtta 510
           |||||||||||||||||||| | |||||||||||||||||||||||||||| |||||||
Poty : 1402 atgcatcacatgatgggcgttaggcaaggttaattctgtacctcgttctatgaatagtta 1461

BtMV : 511  aatatggtaaccatttaaaagagtgaggttttacctccgttgcttatttctatttcgcat 570
           ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||
Poty : 1462 aatatggtaaccatttaaaagagtgaggttttacctccgttgcttatttctatttcgcat 1521

BtMV : 571  agttccaaaccactaccctcaataggcgtctcacagtgaggttttacctcggaggattct 630
           |||||||||||||||||||||||||||||||| ||||||||||||||||||||||||||
Poty : 1522 agttccaaaccactaccctcaataggcgtctcatagtgaggttttacctcggaggattct 1581

BtMV : 631  acggacggtacacaggtttacaa 653
           |||||||||||||||||||||||
Poty : 1582 acggacggtacacaggtttacaa 1604
```

Figure 1.2.1 Comparison of known *Beet mosaic virus* sequence (BtMV) with unknown swiss chard potyvirus sample sequence (Poty)

Table 1.2.2 Summary of samples of TuMV and CaMV in different peri-urban regions

Region	No. samples	TuMV	CaMV	TuMV & CaMV	None
Nyathona	25	3	12	1	9
Kinale	61	12	16	0	33
Mwea	5	1	3	0	1
Embu	6	0	5	0	1
Giachia	1	0	1	0	0
Kaitheri	2	0	2	0	0
Mathira	4	0	4	0	0
Karatina	4	0	3	0	1
Guti	4	0	1	1	2
Kamuyu-Nyeri	2	1	0	0	1
Kibirigwi	8	0	6	0	2
Mukuha	2	0	2	0	0
Gatanga	2	0	2	0	0
Karuri	3	0	3	0	0
Ngong'	4	0	2	1	1
Kiserian	5	0	2	1	2
Kuranga	8	0	5	0	3
Kirenga	8	6	0	0	2
Kinangop	15	1	0	0	14
Gacheru	4	0	0	0	4
Yang'a					
Mukeu	4	0	0	0	4
Cheese	5	0	0	0	5
Athi River	77	46	2	17	12
Total	259	70	71	21	97

TuMV is more predominant here. They also suggest that mixed infections may not be beneficial for either virus because these do not occur very often.

Swiss chard was also severely affected by an unknown potyvirus. The unidentified swiss chard potyvirus was identified as BtMV confirming the suggestion in the project memorandum.

Research Activity 1.3 Screenhouse experiment to determine the effect of virus on yield in cabbage crops

Even though approximately one year was lost due to problems with black rot and mixed viral infection successful, clear results were obtained in February 2002 shown in Figure 1.3.2.

Both TuMV singly and TuMV and CaMV in combination significantly reduced cabbage yield by approximately 40% compared to the control. CaMV did not affect the yield of cabbage.

Discussion

From these results it can be suggested that TuMV significantly reduced cabbage yield whereas CaMV did not have a negative effect. The results from the TuMV + CaMV treatment suggested that reduction in yield was due to TuMV rather than CaMV. These results had a significant impact on activity 1.4 where originally the effect of timing of TuMV and CaMV infection on cabbage yield were going to be assessed. It was decided that subsequently only the impact of timing of TuMV on yield would be assessed. This also has implications for control of CaMV in that it suggests that TuMV is a higher priority both because of the negative impact on yield and the difficulty with which it is controlled due to the non-persistent nature in which it is transmitted. In a field situation CaMV may have a higher impact on yield with constant aphid pressure, in the screenhouse samples were only inoculated once therefore giving the virus a limited chance of successful transmission and subsequent infection.

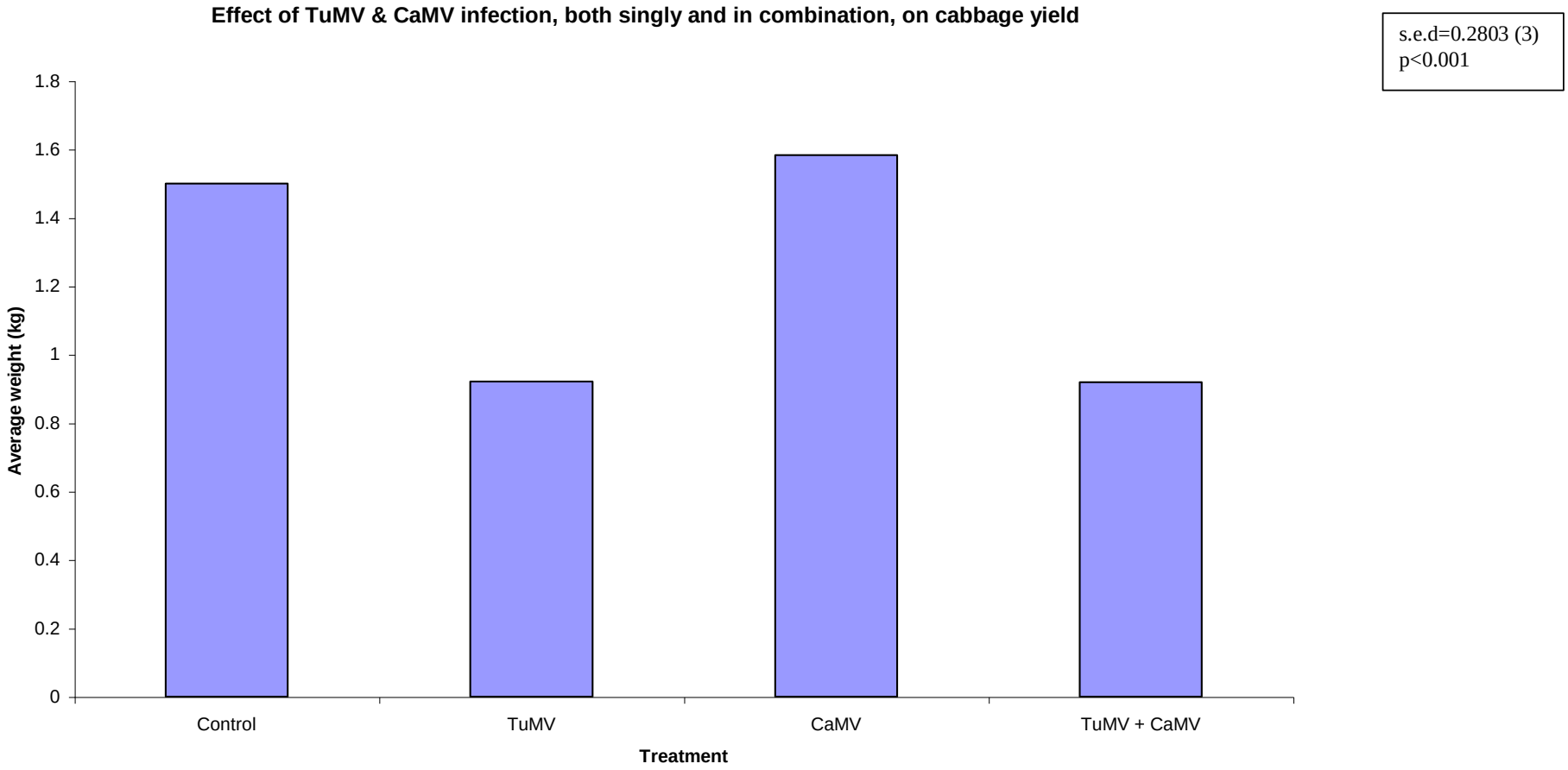


Figure 1.3.2 Results of the effect of Turnip mosaic virus (TuMV) and Cauliflower mosaic virus (CaMV) on yield of cabbage

Research Activity 1.4 Screenhouse experiments to determine effect of the timing of virus infection

The effect of timing of TuMV infection on cabbage yield is shown in Figure 1.4.3 (season 1) and Figure 1.4.4 (season 2). Both early and late infections significantly reduce the yield of cabbage compared to the control in both seasons. In addition, early infection significantly reduced yield (approximately 50% reduction compared to the control) in comparison to late infection (approximately 25% reduction in comparison to the control). In season 2, the number of marketable heads was the same for each treatment. The results also validate the results obtained in activity 1.3 because the effect of TuMV on yield is similar in both experiments even though they were carried out in different seasons.

The effect of timing of TuMV infection on kale is shown in Figure 1.4.5. The number of marketable leaves for each treatment was not significantly different, however late infection significantly reduced the weight of marketable leaves compared to both early infection and the control. Early infection did not have a significant impact on yield.

Discussion

In cabbage it is interesting that TuMV infection had no impact on the number of marketable heads produced but both early and late infection had a negative impact on yield. It is also interesting that early infection significantly reduced head weight compared to late infection. The results strongly indicate that it is more important to control virus infection in cabbage at the seedling stage. Farmers currently spray the transplanted cabbage crop as well as the nursery in an attempt to control virus disease, but these results suggest that this may be unnecessary as the diseases are already established. The benefits of managing seed beds with alternative management strategies for control of virus have been investigated in activities 2.1 and 2.2.

Kale was slightly different in that late infection had a more negative impact on yield. This suggests that control of virus infection in the field is more important than control in the nursery.

Figure 1.4.3 Effect of timing of TuMV infection on yield of cabbage, season 1

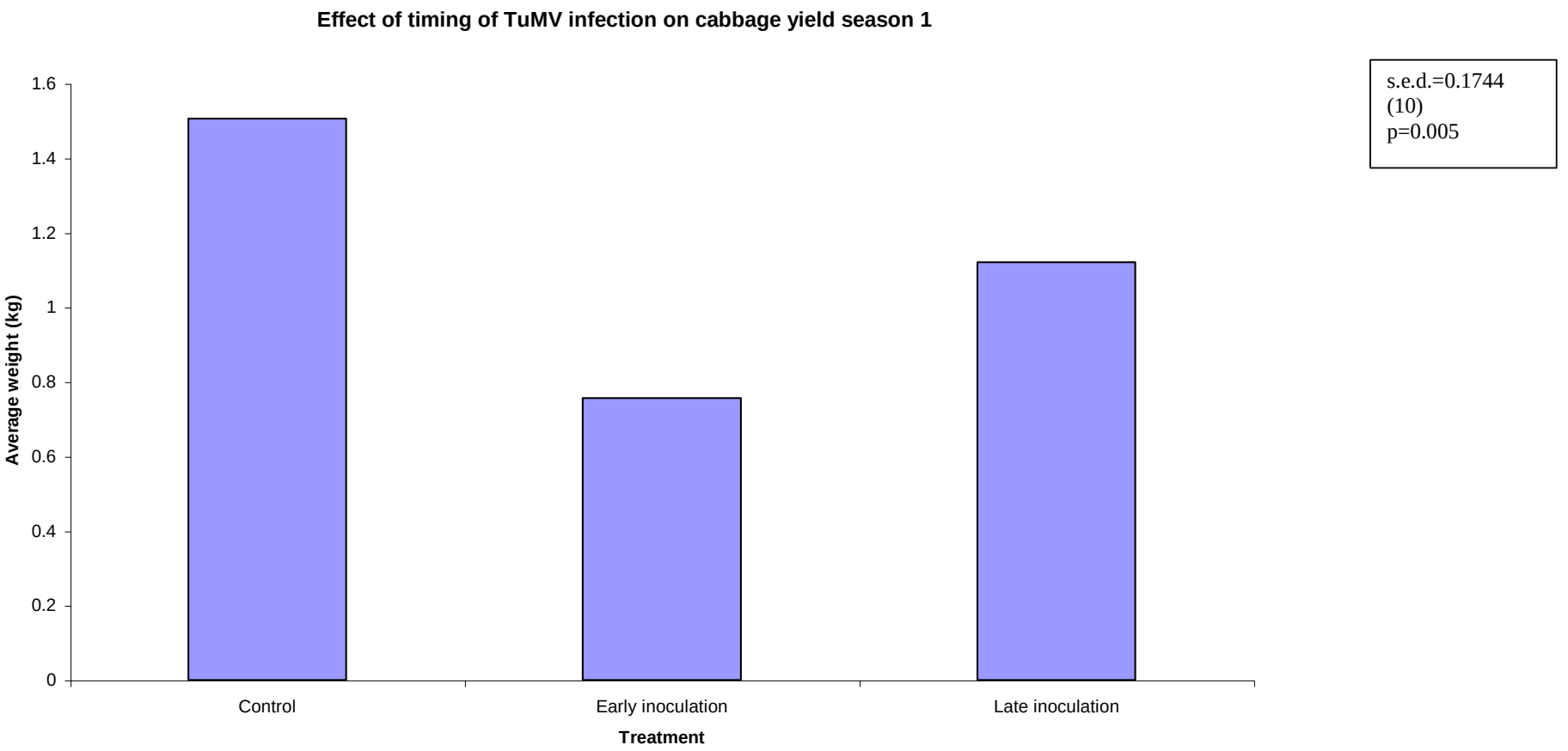


Figure 1.4.4 Effect of timing of TuMV infection on cabbage yield, season 2

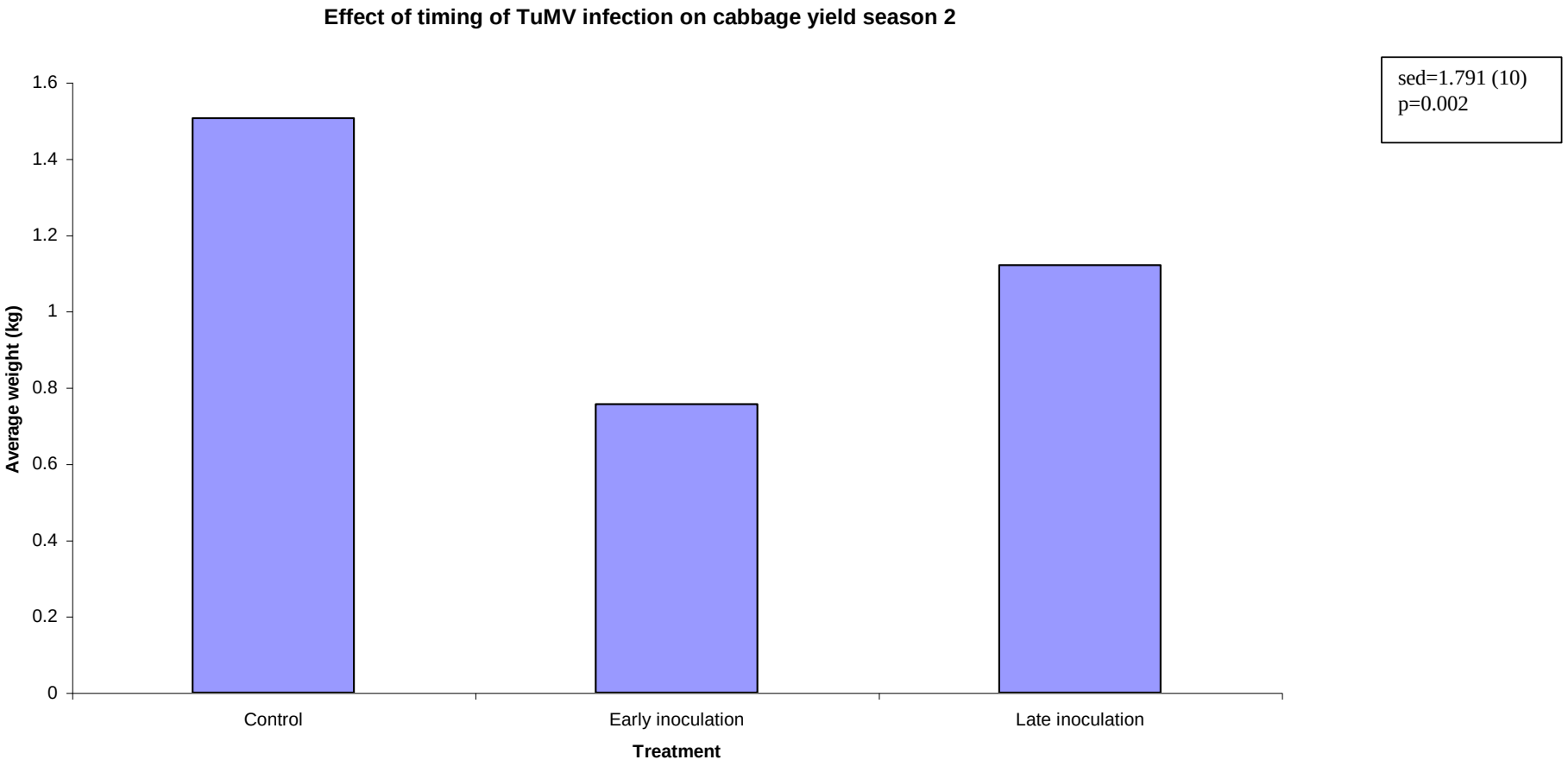
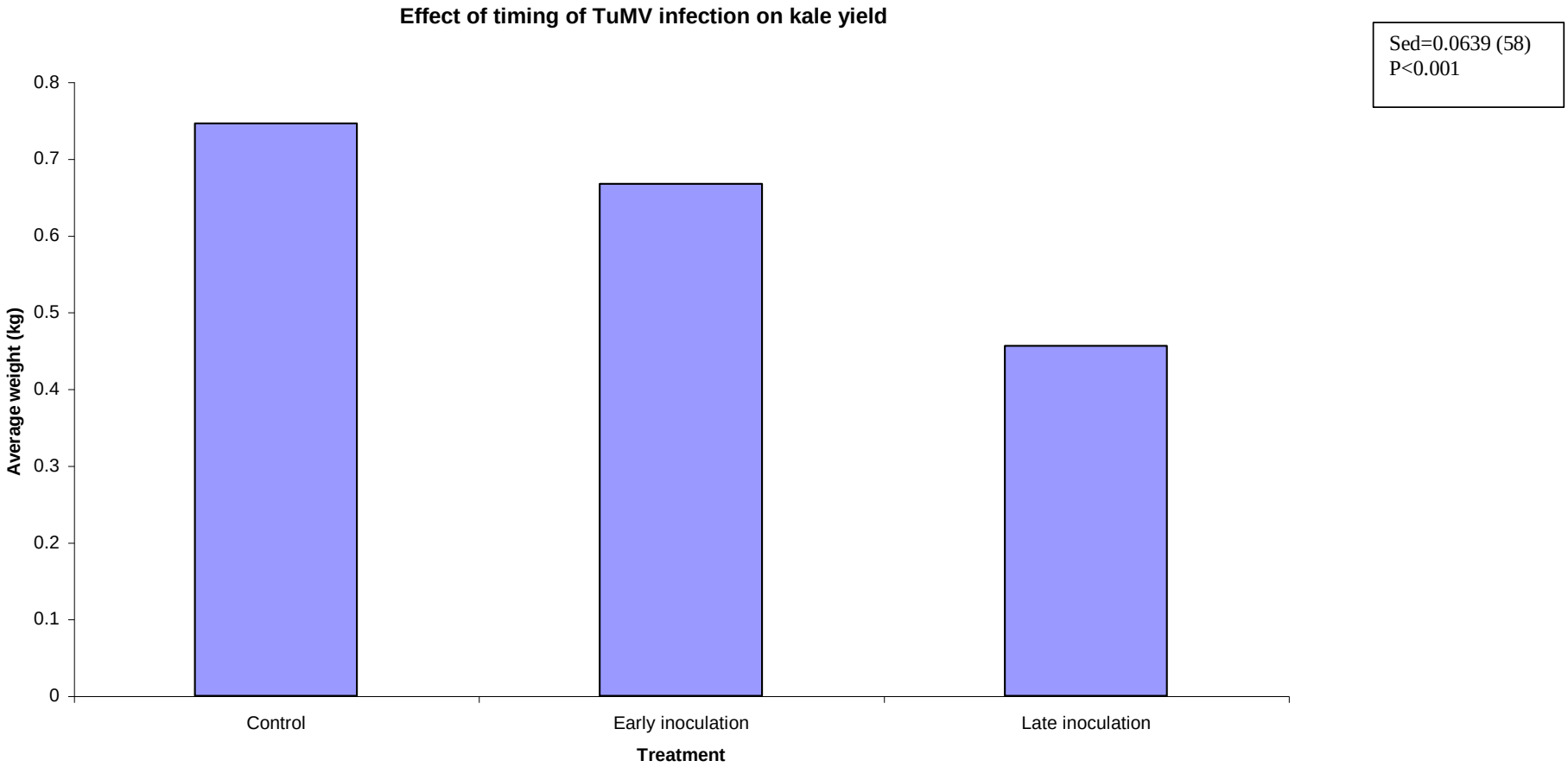


Figure 1.4.5 Effect of timing of TuMV infection on kale yield



Research Activity 1.5 Screenhouse experiment to determine the effect of BtMV on the yield of spinach

The effect of BtMV on number and weight of marketable and nonmarketable leaves and stem and root weight is shown in Figure 1.5.3. Both early and late infections significantly reduced the number and yield of marketable leaves in comparison to the control but were not significantly different from each other. In contrast, the number and yield of nonmarketable leaves increased significantly in both early and late infections and late infection had significantly more nonmarketable leaves and yield than early infection. As well as having an effect on leaf weight, both early and late infections had a significantly negative impact on stem and root weight.

Discussion

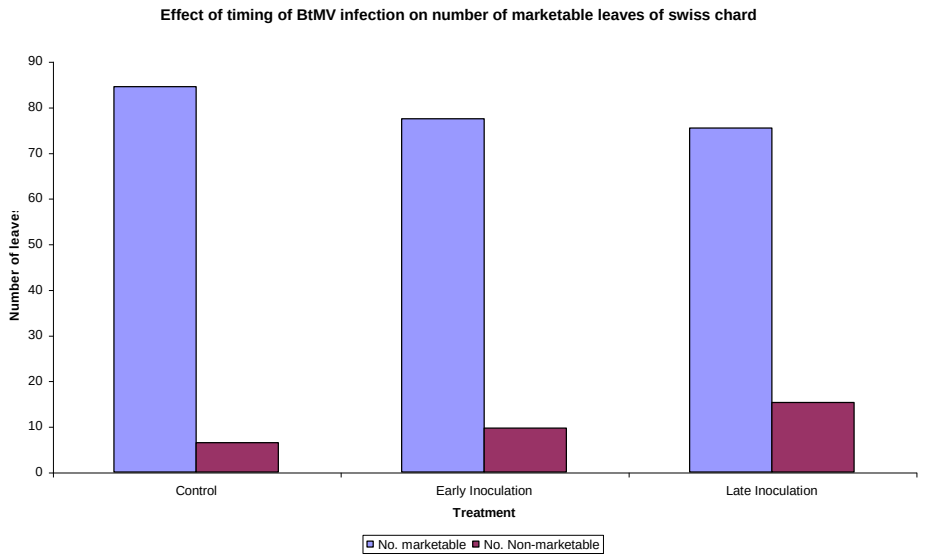
In swiss chard, BtMV had a significantly negative impact on the number and weight of marketable leaves. As for kale infected with TuMV in activity 1.4, late infection produced significantly more unmarketable leaves than early infection. As swiss chard is harvested continually and sold at market, these results suggest that it would be more important to protect the crop when it is in the field as well as in the nursery.

Research Activity 2.1 To investigate methods to protect Brassica seed beds from virus infection

In both season 1 and season 2 at Thika, no significant differences were observed between either theaverage number of heads obtained or the average weight. At Kabete in season 1 both the number of heads and weight were significantly increased by the fleece and straw treatments (Figure 2.1.1) however in season 2 no significant differences were observed.

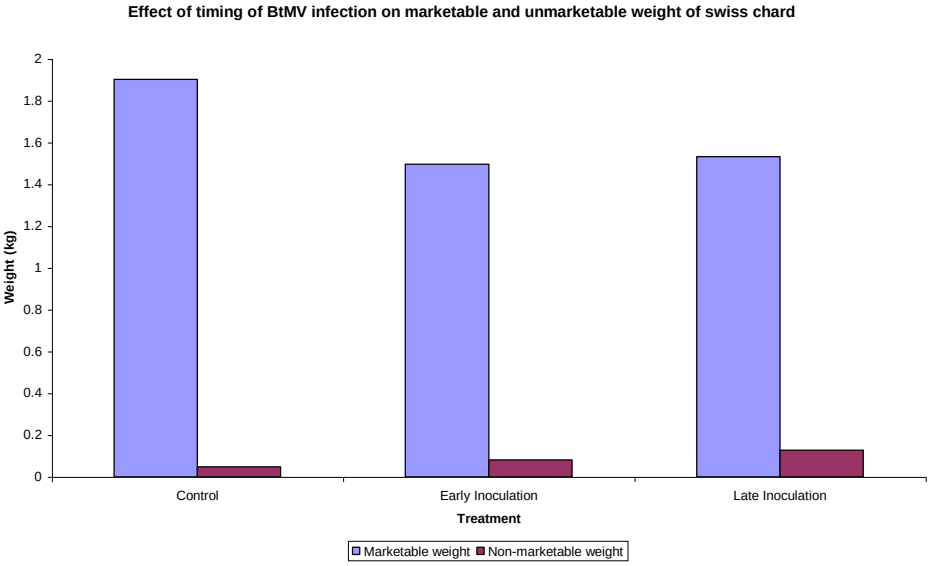
In season 1, at both Thika and Kabete, there were no significant differences in aphid numbers between the treatments. However, upon closer inspection of the results from Kabete both fleece and straw significantly reduced aphid numbers up to five weeks into the experiment (Figure 2.1.2). In season 2 at Kabete the straw mulch in the nursery to straw mulch in the field treatment significantly reduced aphid numbers (Figure 2.1.3), however no significant differences were observed at Thika

Figure 1.5.3 Effect of timing of BtMV infection on swiss chard



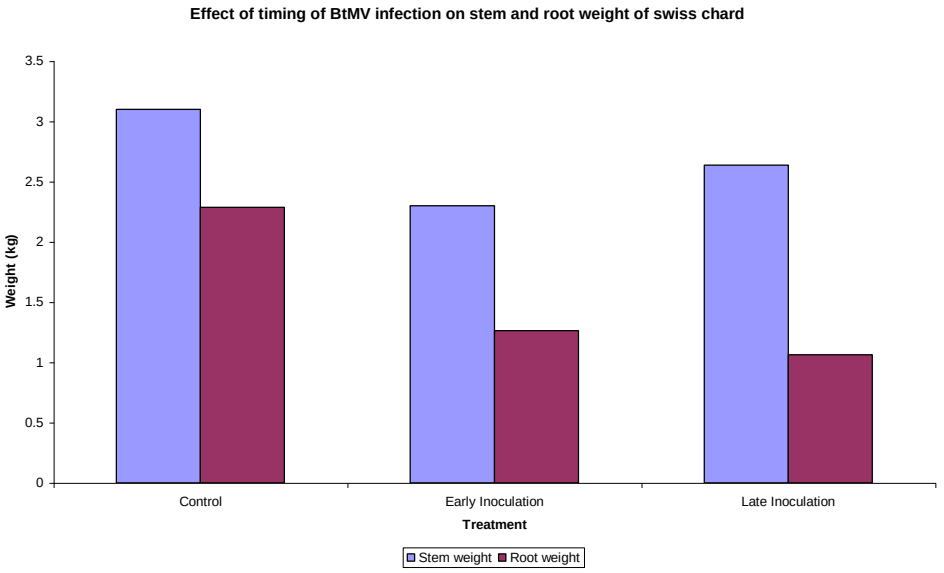
Marketable
s.e.d=1.919 (158)

Non-marketable
s.e.d.=1.412 (158)



Marketable
s.e.d=0.0605 (158)

Non-marketable
s.e.d.=0.01351 (158)



Stem
s.e.d=0.2257 (14)

Root
s.e.d.=0.2103 (14)

Figure 2.1.1 Effect of treatments on average head number and weight of cabbage at Kabete, season 1

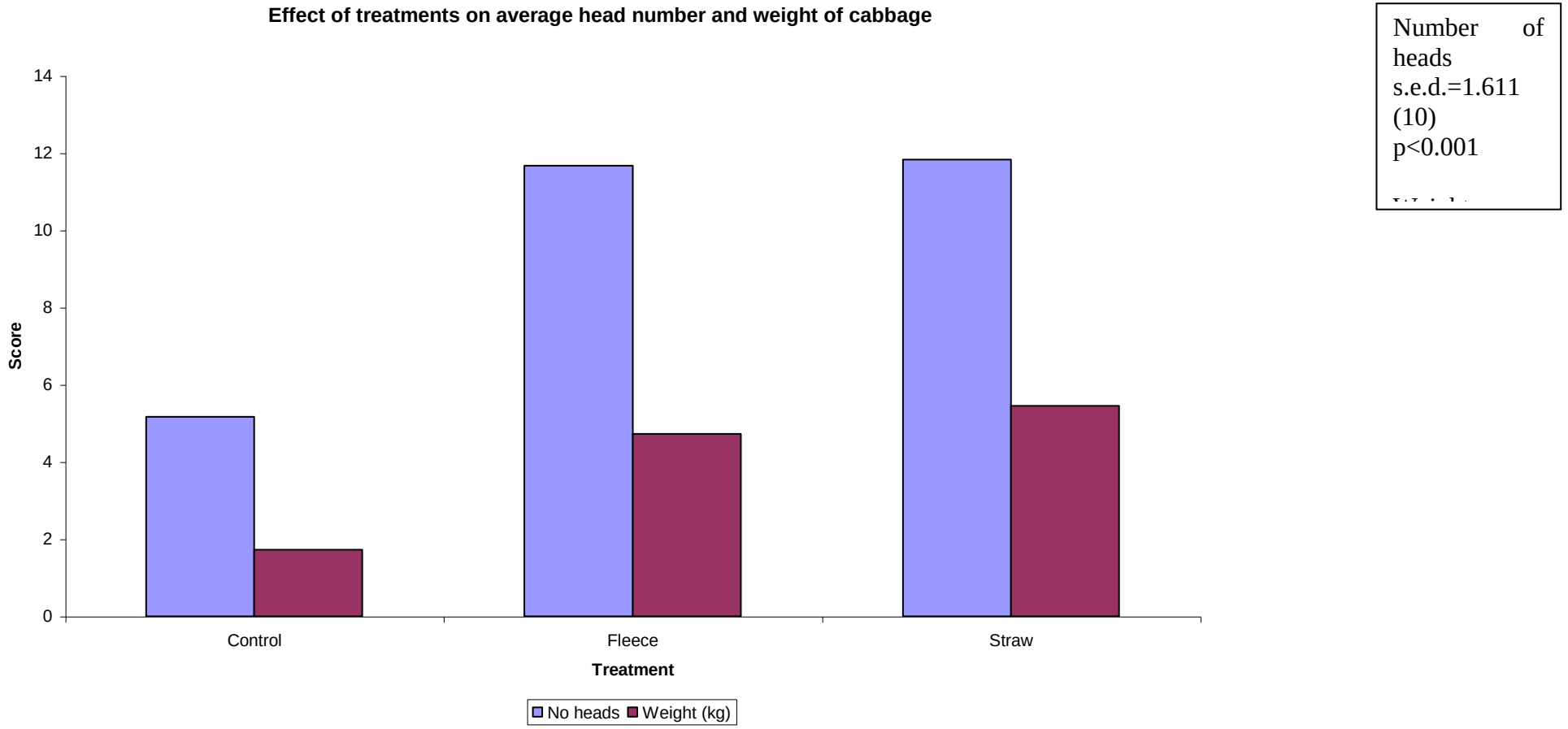


Figure 2.1.2 Combined effect of fleece and straw treatments on aphid numbers at Kabete, season 1

s.e.d=0.0931 (10)

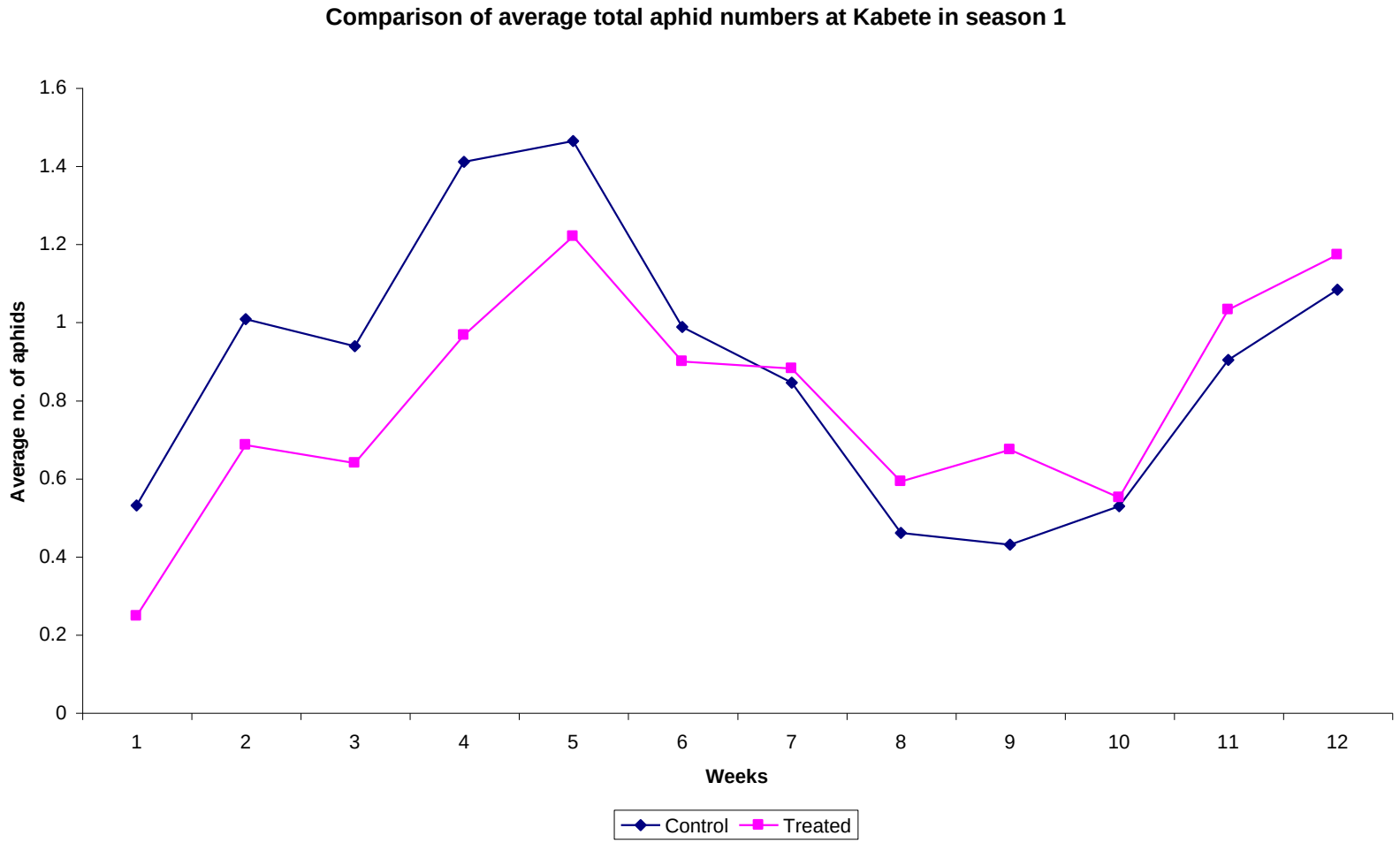
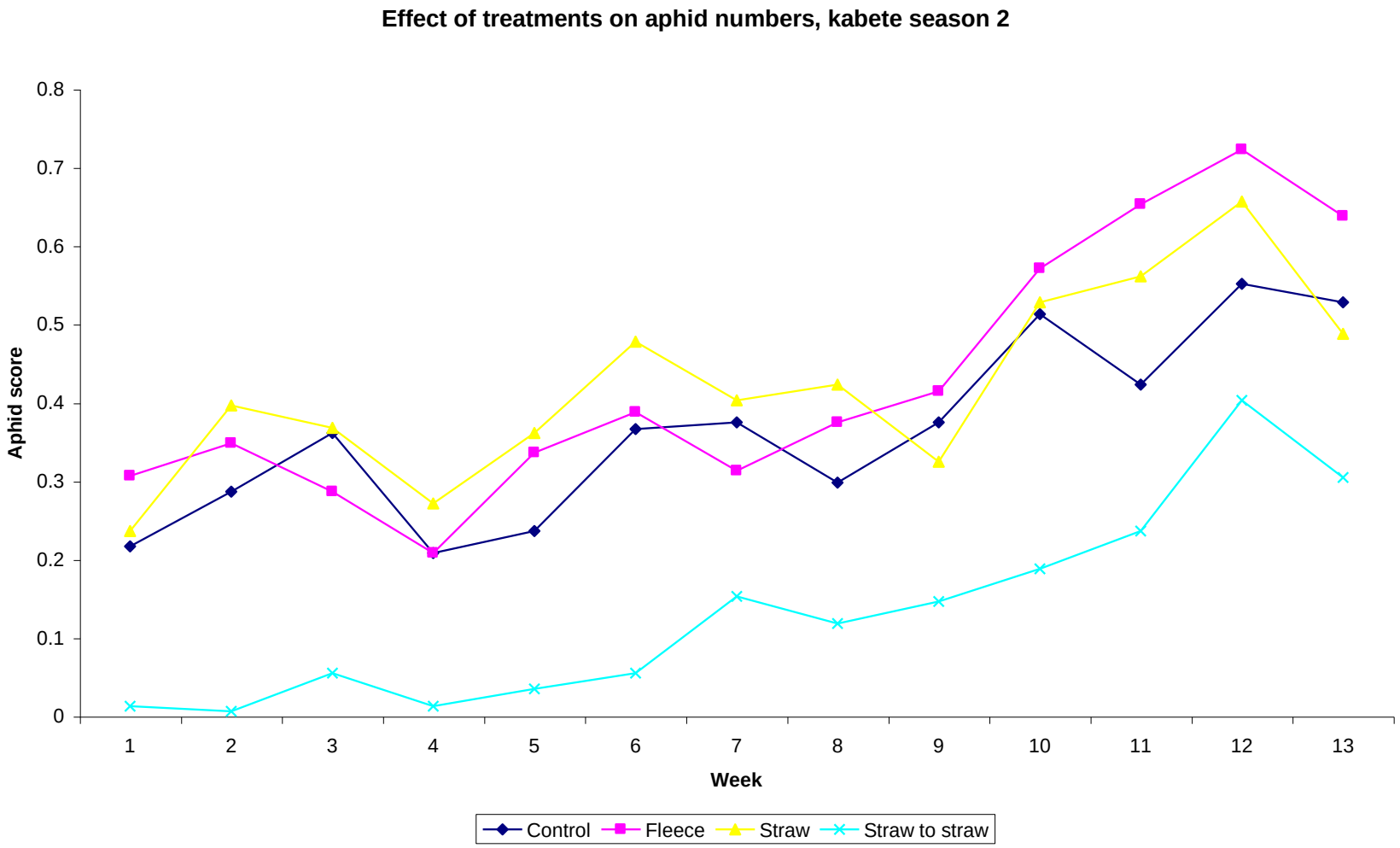


Figure 2.1.3 Effect of treatments on aphid numbers at Kabete, season 2

s.e.d=0.06738 (15)



In season 1 no significant differences were observed at Thika. However, at Kabete both treatments significantly reduced virus incidence compared to the control, but there were no significant differences between fleece and straw treatments (Figure 2.1.4). In season 2 at both sites, the straw mulch in the nursery to straw mulch in the field treatment significantly reduced virus incidence (Figure 2.1.5). At both sites and in both seasons virus incidence increased with increasing numbers of aphids (Figure 2.1.6).

Diamond back moth (DBM) numbers were not significantly affected by the treatments. However, in season 2 at both sites the straw in the nursery to straw in the field treatment caused a significant increase in DBM numbers (Figure 2.1.7).

For Black Rot, no significant differences were observed overall. However, upon closer inspection of data from Kabete in season 1 incidence of black rot was significantly lower in fleece up to seven weeks into the experiment and then significantly more in week 12. In the straw treatment, incidence of black rot was significantly lower up to week 6 and then significantly higher in weeks 10 to 12. Data was also collected for incidence of thrips, whitefly, downy and powdery mildew however no significant differences were observed.

Discussion

The results of this activity in season 1 show that both fleece and straw had a significant effect on aphid and virus incidence. In season 2, the extra treatment of straw mulch in the seed-bed plus straw mulch in the field significantly reduced virus and aphid incidence compared to both treatments used in season 1 and the control. This effect can be explained by the relationship between aphid numbers and virus incidence (Figure 2.1.6). The double dose of straw mulch (i.e. in nursery and field) may act by confusing the aphid landing signals, hence reducing aphid feeding and subsequent virus transmission.

Figure 2.1.4 Effect of treatments on virus incidence at Kabete, season 1

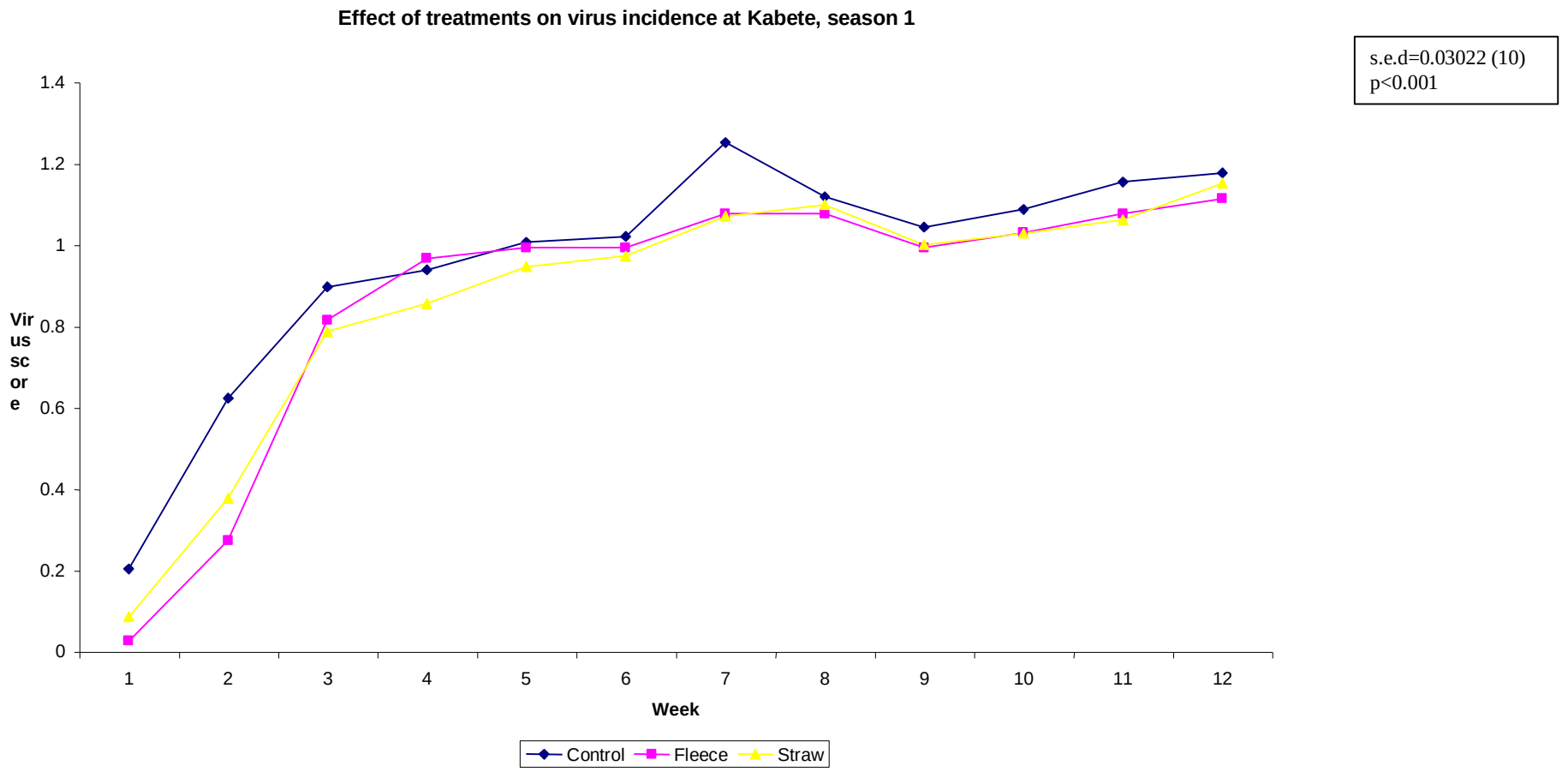
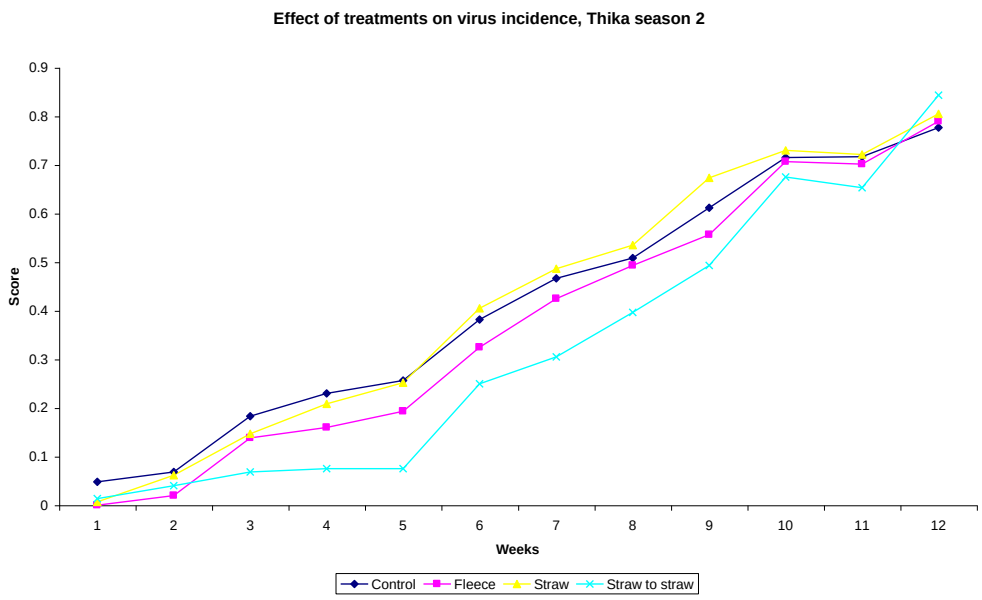


Figure 2.1.5 Effect of treatments on virus incidence at Thika and Kabete, season 2



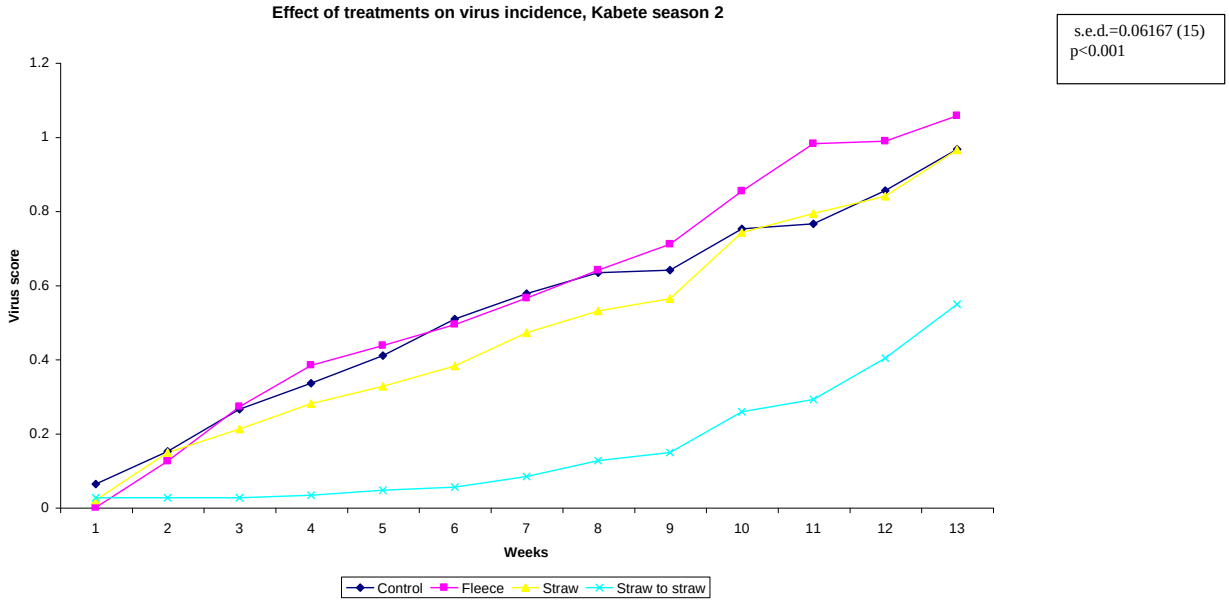


Figure 2.1.6 Relationships between aphid numbers and virus incidence at (a) Thika, season 1; (b) Thika, season 2; (c) Kabete, season 1; (d) Kabete season 2

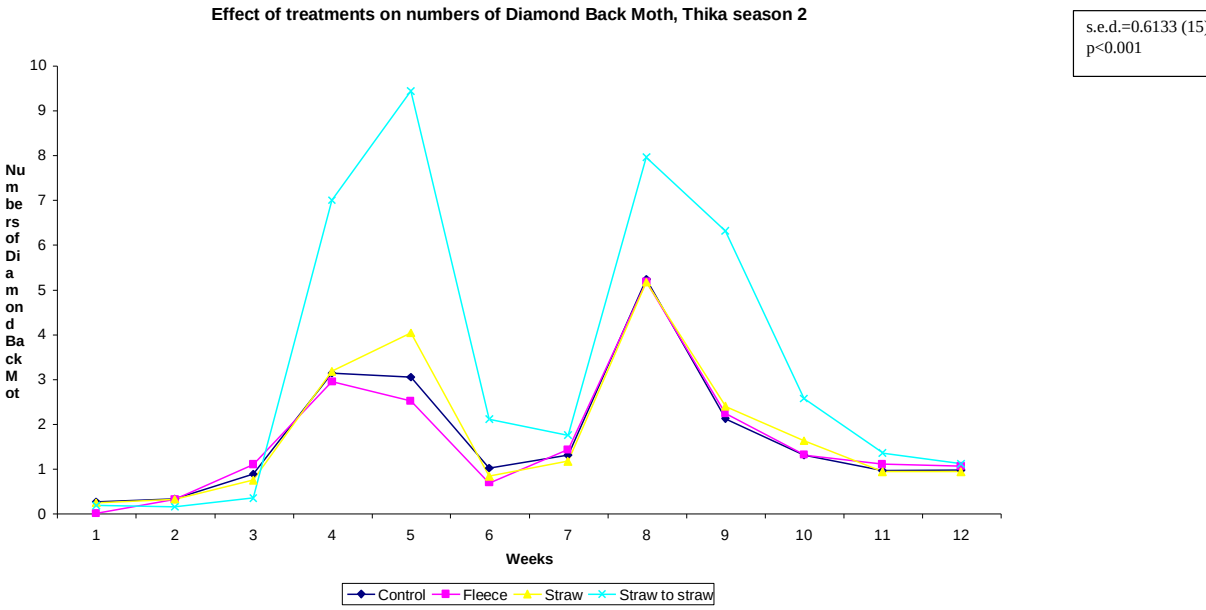
(a)

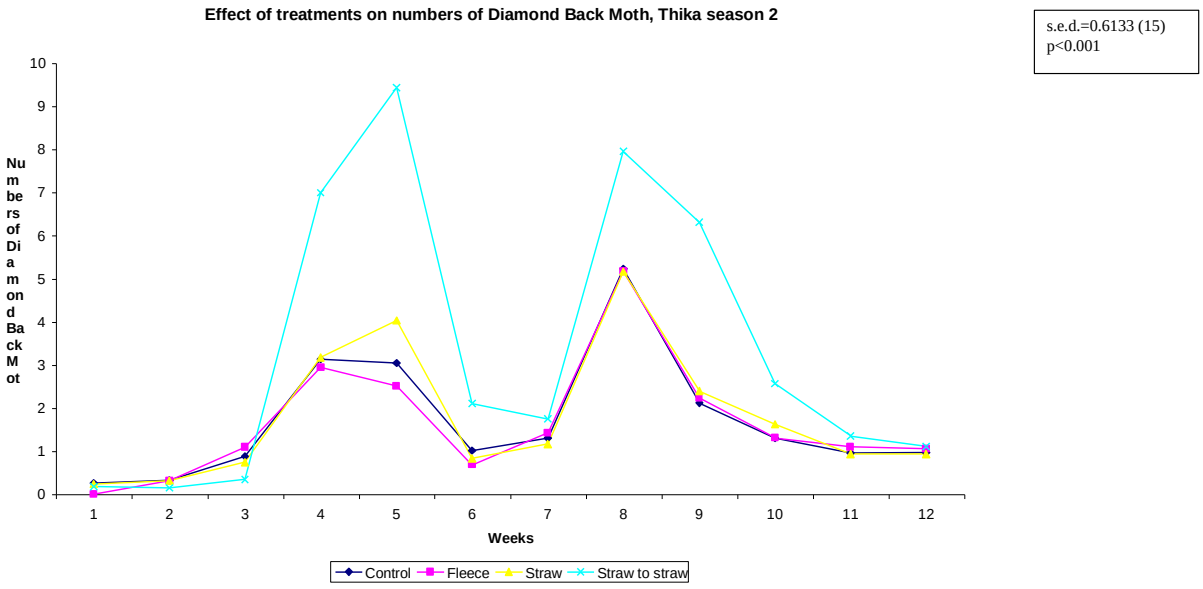
(b)

(c)

(d)

Figure 2.1.7 Effect of treatments on diamond back moth numbers at Thika and Kabete, season 2





The results obtained with DBM numbers suggest that straw mulch may increase the incidence of DBM and possibly black rot. These results highlight the need for an integrated approach to controlling pest and disease management.

Research Activity 2.3 Evaluation of farmer acceptability of alternative control strategies

A more detailed account of research activity 2.3 can be found in Njuki, 2001 (Appendix 4).

2.3.1 Results of initial PRA activity

Farmers at Athi River and Ruiru identified indicators of wealth. Social categories that were important included asset ownership, financial ability, type of household and education level. Categories and definitions of wealth indicators are given in Table 2.3.1 and will be used to calculate a wealth index, which will be used in the final PRA activity 4.2.

2.3.2 Results of Participatory Budgeting activity

The statistical partial budgets (Table 2.3.2) gave similar results to the farmer budgets (Table 2.3.3) with dimethoate to dimethoate, dimethoate to mulch and fleece to no mulch with positive benefits in both budgets. The fleece to mulch treatment was the only treatment that had negative benefits in the farmer budget that resulted in positive benefits in the statistical budget. The rest had negative benefits in both budgets.

2.3.3 Results of evaluation of treatments

Table 2.3.4 shows the ranking of treatments according to criteria important for adoption of a particular treatment. In Athi River the dimethoate was ranked top in terms of benefits and disease control and the control ranked worst. However in terms of labour and use of other inputs the results were reversed with the control ranked top and the dimethoate ranked bottom. The farmers in Kariguini, an organic group, ranked mulch as top for benefits and

Table 2.3.1 Wealth indicators for Athi River and Ruiru

Rich	Medium	Poor
Athi River		
6 to 20 grade cows	1 to 5 cattle	0 cattle
11 to 50 goats	6 to 10 goats	0 to 5 goats
Hire land of >4 acres	Hires land of ½ to 3 acres	No land (squatting)
House with stone wall and iron sheet roofing	House with iron sheet wall and roof	Paper house
Has access to irrigation water	Has access to irrigation water	No access to irrigation water
Has irrigation equipment	Rent or borrow irrigation equipment	No irrigation equipment
Has permanent hired labour	Uses own labour and sometimes hires	Provides own labour
Grows irrigated crops for export- French beans, flowers, okra etc	Grows irrigated maize, kales, beans, French beans, cabbage, tomatoes and chillies for local market	Grows rain fed maize, beans and kales
Has enough operating capital	Minimum operating capital	No operational capital
Have modern farming experience or hire experienced managers.	Uses traditional and modern farming experience	Uses traditional farming experience
Ruiru		
Multistorey house with tiled roof	Stone walled house with iron sheet roof	Brick walled house with iron sheet roof
1 to 2 motorcars	One bicycle	1 wheelbarrow
3 acres of vegetables, access to fertiliser and quality seed	1 acre of vegetables, not enough fertiliser or quality seed	No inputs, borrows seeds and no fertiliser applied
50 hp irrigation pump, tractor, sprinklers	3 to 4hp irrigation pump, no tractor, no sprinklers and uses pipes	Bucket irrigation or money maker
Has hired labour	Uses own or casual labour	Uses own labour only
2 to 5 grade cows, 0 local cattle	1 grade cow or 3 to 15 zebu animals without grade cows	0 to 2 local cattle
Children attend private boarding school	Children attend local government school	Children do not attend school
Meat in diet everyday	Meat in diet once a month	No meat in diet
Ksh 30,000 and above operating finance	Ksh 5000 to 30,000 operating finance	Ksh 5000 and below operating finance

Table 2.3.2 Statistical partial budget (on a per ha basis)

	Control to mulch	Mulch to Mulch	Mulch to no mulch	Fleece to mulch	Dimethoate to mulch	Fleece to no mulch	Dimethoate to Dimethoate
Inputs	118 915	119,219	304.2	119 213	119 077	298.8	18 019
Output	85 978	103 174	31 084	186 507	206 349	89 947	263 888
Extra output	41 666	58 862	-13 227	142 195	162 037	45 634	219 576
Benefits (Ksh)	**-77 248**	**-60 357**	**-13 532**	**22 982**	**42 960**	**45 336**	**201 588**
Benefits (UK£)	**-702.3**	**-548.7**	**-123.0**	**208.9**	**390.5**	**412.1**	**1 832.6**
Rank	**7**	**6**	**5**	**4**	**3**	**2**	**1**

Table 2.3.3 Calculating the benefits

	Mulch to Mulch	Control to mulch	Mulch to no mulch	Fleece to mulch	Fleece to no mulch	Dimethoate to mulch	Dimethoate to Dimethoate
Extra output	82.1	56.35	-18.9	196.85	74.6	243.40	372.85
Extra Costs	213.55	179.8	33.75	213.05	33.25	197.8	45
Benefits	**-131.45**	**-123.4**	**-52.65**	**-16.2**	**41.35**	**45.6**	**327.85**
Rank	**7**	**6**	**5**	**4**	**3**	**2**	**1**

Table 2.3.4 Farmers ranking of treatments in Athi River and Kariguini, where 1 = best and 4 = worst

Treatment	Criteria									
	Labour		Benefits		Availability		Disease Control		Use of other inputs	
	Athi River	Kariguini	Athi River	Kariguini	Athi River	Kariguini	Athi River	Kariguini	Athi River	Kariguini
Mulch	3	2	3	1	3	1	3	1	2	1
Fleece	2	1	2	2	4	4	2	2	3	2
Spraying	4	4	1	4	2	3	1	3	4	3
Control	1	3	4	3	1	2	4	4	1	4

Table 2.3.5 Merits and demerits of treatments by farmers in Athi River and Kariguini

Treatment	Athi River		Kariguini	
	Merits	Demerits	Merits	Demerits
Mulch	• Ability to retain water and moisture • Control pests (aphids) and therefore viral diseases • Controls weeds • Prevents contact of plant with the ground	• Expensive • Can keep other pests such as crickets and cutworms • May retain more moisture than necessary during heavy rains and after watering	• Easily available • Protects soil from direct sunlight • Preserves moisture • Increase soil fertility • Weed control • Control of aphids • Can be used many times	• Is dusty and can hurt the skin • Arsonists can burn your shamba • Can carry seeds for other weeds • Snakes and reptiles can hide
Fleece	• Seedlings were of better quality than other treatments • Little labour required • Kept aphids out and hence controlled the disease • Yield was high • Retains moisture	• Expensive • Seedlings etiolated • Not easily available • Had weed problems	• Prevents aphids and all other insects • Higher yield • Can be used many times • Protects seedlings from the sun • Easier and moderated watering • Seedlings grew faster • Protected seedlings from physical damage e.g. people stepping on them	• Not locally available • No knowledge of cost if it was available locally • Can not be used in the whole field • Can be stolen
Spraying	• Controlled most pests and hence diseases • Yield was high • Good quality heads • Affordable	• Offensive smell • Labour intensive • Expensive to apply (need pump, masks, gloves etc) • Could be toxic • Pests develop resistance • Farmer may buy when it has expired • Takes long to degrade	• Is easy to use • Can be used against many pests and diseases • Leaves of cabbages and kales are healthy	• Makes people sick – poisoning • Kills beneficial insects • Requires many other accessories e.g. gloves • Destroys the soil • Pollutes the atmosphere • Are expensive • You can not access it unless you buy from the shop – have to use money • Low farmer knowledge of which chemicals are bad or good • Storing it in the house is risky

disease control whereas dimethoate was ranked last for benefits and third for disease control.

Table 2.3.5 shows the advantages and disadvantages of each treatment according to each group of farmers. Even though farmers in Athi River ranked dimethoate top for benefits and disease control in the criteria for adoption exercise in the merits and demerits exercise it had the most demerits of all the treatments.

In Athi River from the general score out of 100 dimethoate was top (score 50), fleece was second (score 25), mulch was third (score 15) and the control was last (score 10). In Kariguini, mulch was top (score 40), fleece was second (score 30), dimethoate was third (score 20) and the control was last (score 10).

Agreement by farmers to try the disease control strategies on their farms

The two groups of farmers in discussion with the project team agreed to try the disease control strategies, specifically the mulch and fleece, on their farms during the next planting season. The project team will provide the fleece to the groups.

Discussion

It is interesting that the farmers in Athi River preferred dimethoate even thought this had the longest list of demerits of all of the treatments. It is also interesting that Kariguini, as an organic group of farmers, preferred the mulch treatment and ranked the dimethoate as worst. Farmers in Kariguini have easy access to mulch because they can raise it themselves so do not have to purchase it. This decreases inputs required therefore increases the benefits. However, farmers in Athi River have to purchase mulch and have no way of raising it themselves so will look at the overall positive impact on the yield of their crops rather than the health benefits to workers or final consumers. Fleece was also favourable but needs to be more readily available to the farmers for it to be adopted. This baseline data will be used in the wider promotion of virus disease management strategies proposed in a current concept note (CN801) to the CPP.

Research Activity 3.1 To determine pathotype variability of TuMV isolates

The variability of 20 TuMV isolates were determined using the differential pathotyping system as described by Jenner & Walsh (1996). All isolates tested were pathotype 1 (Table 3.1.2).

To further assess variability of isolates serotypic analysis was used. A panel of monoclonal antibodies (Jenner *et al*., 1999) was used to group isolates into three serotypic groups (Table 3.1.2).

CaMV isolates could be divided into three serotypic groups (Table 3.1.3). However, these are preliminary results because the groupings could not be consistently repeated as the plants got older. Attempts at producing consistent results by altering the protocol, using sonication and alterations in the pH of buffers were unsuccessful.

Discussion

The pathotypic group into which the TuMV isolates were grouped, pathotype 1, is the most common pathotypic group in the world (Jenner & Walsh, 1996). The lack of pathotypic variation suggests that it would be relatively simple to deploy resistance to TuMV to protect crops. However, this may create a selection pressure for more virulent pathotypes as even though the isolates fall into the same pathotype they fall into three different serotypes which suggests that TuMV has mutated and could easily mutate to overcome resistance if selection pressure was exerted.

The classification of CaMV into serotypic groups needs further work because the sensitivity of the test is affected by age of the plant. A method for classifying CaMV isolates would be useful to measure variation in virus populations for the deployment of resistance as a control strategy.

Research Activity 3.2 Evaluate local cultivars of cabbage and kale for resistance to TuMV and CaMV and a local cultivar of swiss chard for resistance to BtMV

Local cultivars of cabbage, kale and swiss chard have been screened for resistance to TuMV and CaMV. Nine out of the ten lines tested had resistance to TuMV, the one line tested with BtMV had resistance, however none of the lines tested showed any resistance to CaMV (Table 3.2.1). TuMV and BtMV resistant plants were taken forward for selfed seed

Table 3.1.2 Pathotypic and serotypic groupings of TuMV isolates.

* Isolates unable to be revived for further analysis.

TuMV Isolate	Pathotype	Serotype
334/16	1	*
334/29	1	BEL 1
334/30	1	*
334/32	1	*
334/45	1	BEL 1
334/68	1	*
472/12	1	BEL 1
472/18	1	Subtype UK 1
472/48	1	Subtype CDN 1
472/93	1	*
472/97	1	Subtype CDN 1
472/142	1	BEL 1
472/144	1	BEL 1
472/145	1	Subtype CDN 1
472/148	1	Subtype UK 1
472/156	1	Subtype UK 1
472/162	1	Subtype UK 1
472/163	1	Subtype UK 1
472/170	1	Subtype UK 1
472/184	1	Subtype UK 1
472/222	1	Subtype CDN 1
472/252	1	BEL 1
472/256	1	BEL 1

Table 3.1.3 Preliminary classification of three CaMV isolates

Antibody	Isolate 472/137	Isolate 472/51	Isolate 472/95
EMA 195	-	+	+
EMA 196	+	+	+
EMA 199	+	+	+
EMA 200	+	-	-
EMA 201	-	-	-

Table 3.2.1 Brassica napus, B. oleracea and Spinacia oleracea tested for resistance to Turnip mosaic virus (TuMV), Cauliflower mosaic virus (CaMV) and Beet mosaic virus (BtMV)

Seed Lot	Origin	Type	No resistant plants/Total no. plants tested		
			TuMV	CaMV	BtMV
Giant English	Commercial variety	*Brassica napus*	26/95	-	-
Big Cropper	Commercial variety	*Brassica oleracea* (cabbage)	0/85	-	-
Glory of Enkhuizen	Commercial variety	*Brassica oleracea* (cabbage)	2/88	-	-
11	Alice, Kirenga market	*Brassica oleracea* (kale)	4/60	0/29	-
12	Kirenga market	*Spinacia oleracea*	-	-	12/40
13	Anne Wangare, Kirenga market	*Brassica oleracea* (kale)	11/58	0/27	-
14	Kirenga market	*Brassica oleracea* (kale)	5/45	0/26	-
15	Kirenga market	*Brassica oleracea* (kale)	5/50	0/29	-
16	Jane Kisumi, Kinale	*Brassica oleracea* (kale)	6/56	0/29	-
17	Jacinta Wanjiku		9/79	0/29	-

production. Unfortunately resistant plants from Giant English and Glory of Enkhuizen were susceptible to mildew and blackrot so seed production was not possible.

Discussion

Big Cropper was the only *B. oleracea* variety that did not have any resistance to TuMV, the rest of the seed lots had resistance, some of which has been taken forward for seed production. No CaMV resistance was identified in *B. oleracea*, although virus levels were lower than in TuMV susceptible plants suggesting there may have been a degree of tolerance. The *S. oleracea* line had some resistance to BtMV and one plant has been taken forward for seed production. The non-persistent mode of transmission of TuMV and BtMV makes it difficult to control because chemicals are ineffective in controlling the spread of virus, therefore plant resistance may be a more effective control strategy. It is important to characterise the genetic control of resistance so that it can eventually be deployed to produce TuMV and BtMV resistant varieties.

Research Activity 3.3 Screen promising cultivars and land races

Figure 3.3.1 shows a summary of differences for proportion of marketable plants and proportion of infected plants at both NARL and Thika. There were significant differences between the seed lots. Seed lot 17 was consistently lowest for proportion of marketable plants and highest for proportion of infected plants. The score for seed lot 17 was not significantly different from seed lots 1, 2 and 18 for proportion of marketable plants at NARL but it was significantly different from all seed lots at Thika and for proportion of infected plants at both sites. Seed lots 3, 4, 8, 9, 10, 12 and 13 were not significantly different from each other for highest proportion of marketable plants and lowest proportion of infected plants at both sites.

There were higher total number of leaves harvested for all seed lots at Thika than at NARL (Fig. 3.3.2). However, there were significant differences ($P \leq 0.001$) in number of marketable leaves harvested at both sites. Seed lot 17 produced the least number of marketable leaves at both sites. Twelve of the seed lots at NARL produced more marketable leaves than the commercial variety, but at Thika the commercial variety was the most productive.

Similarly, the seed lots produced a greater total marketable weight of kale leaves at Thika than at NARL, and seedlot 17 yielded the lowest weights per season per plot (Fig. 3.3.3). Seed lot 3, 4,

12, and the commercial variety produced the highest total marketable leaf weights at Thika, but at NARL the top four were seed lots 4, 8, and 9.

Several plants which showed resistance/tolerance to viral diseases and insect pests were tagged, and monitored for flowering. However, only three tagged kale plants flowered. The inflorescence of the three plants were covered in order to prevent cross pollination and bird damage. The seed was collected.

Discussion

These results show that there is a direct relationship between proportion of plants infected and proportion of marketable plants. Seed lot 17 had a high proportion of infected plants and a low proportion of marketable plants therefore is not suitable for use on a larger scale where field resistance would be used as a management strategy. Seven of the 18 seed lots tested had a high proportion of marketable plants and a low proportion of infected plants which suggests that there is virus resistance present in the landrace populations selected in Kinale. In addition, three seed lots produced higher total marketable leaf weight per plot per season than several other seed lots. This suggests that there may be diverse germplasm from which selections could be made for a wider breeding programme.

Research Activity 3.4 To determine the potential of self-selection of seed

Plant selection

The objective of the on-farm trial was to select seed from kale land races that showed resistance/tolerance to Brassica viruses. Farmers decided to use the following criteria to select their good and bad plants for seed production:

Good: Green leaves, many thick, long pods, late flowering (long harvest period), soil fertility of the area around which the plant is

Bad: Small seeds, thin leaves, stunted plants, weak plants, short and slender pods, leaf yellowing/chlorosis, immature seeds, aphid-infested plants

Scientists used the following criteria to select plants for seed production:

Good: Aphid infested but still healthy, healthy green leaves, late flowering

Figure 3.3.1 Assessment of seed lots at NARL and Thika for percentage of marketable leaves and infected plants

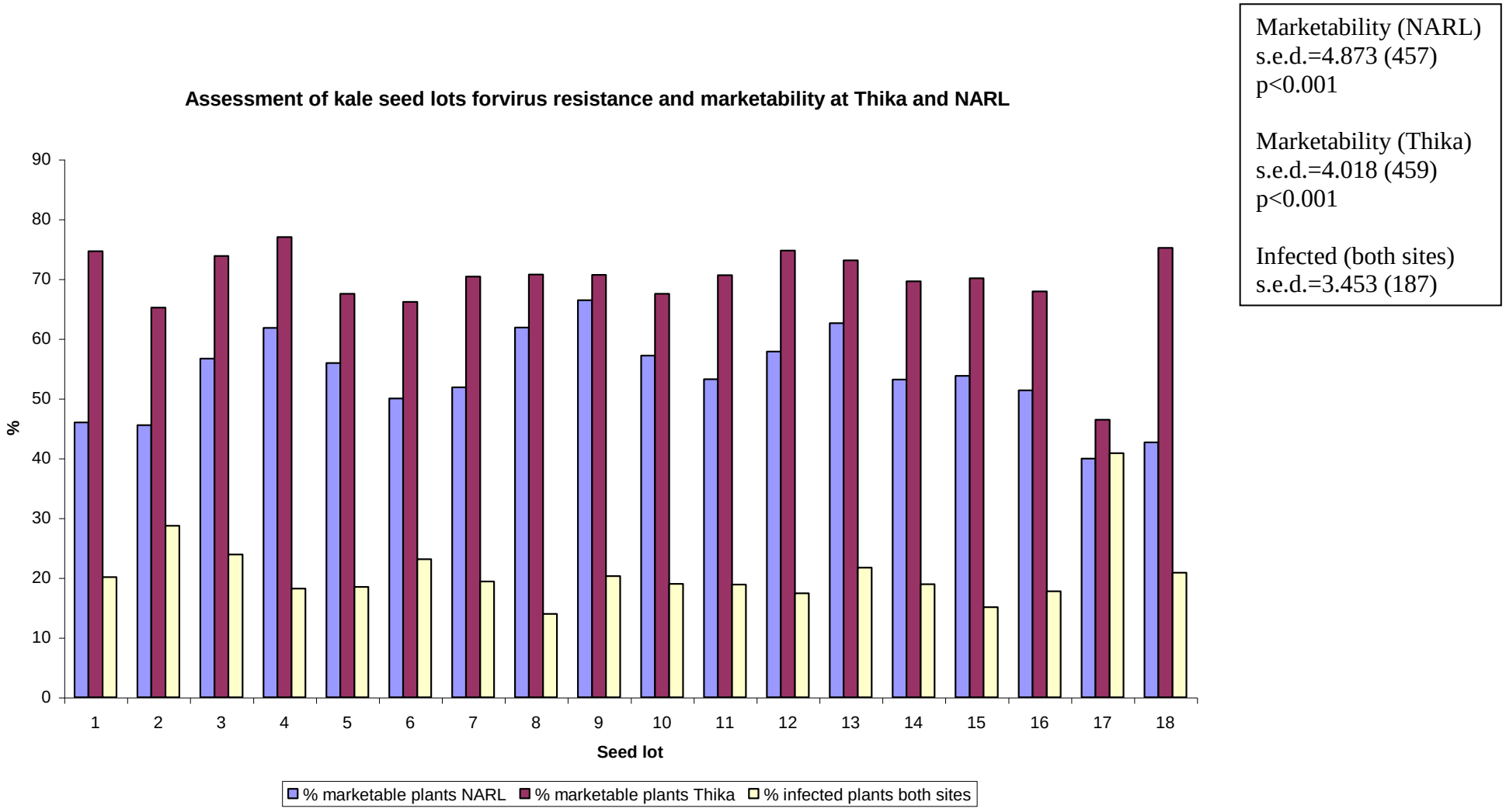


Fig. 3.3.2 Assessment of seed lots at NARL and Thika for total number of marketable leaves per plot harvested over the season

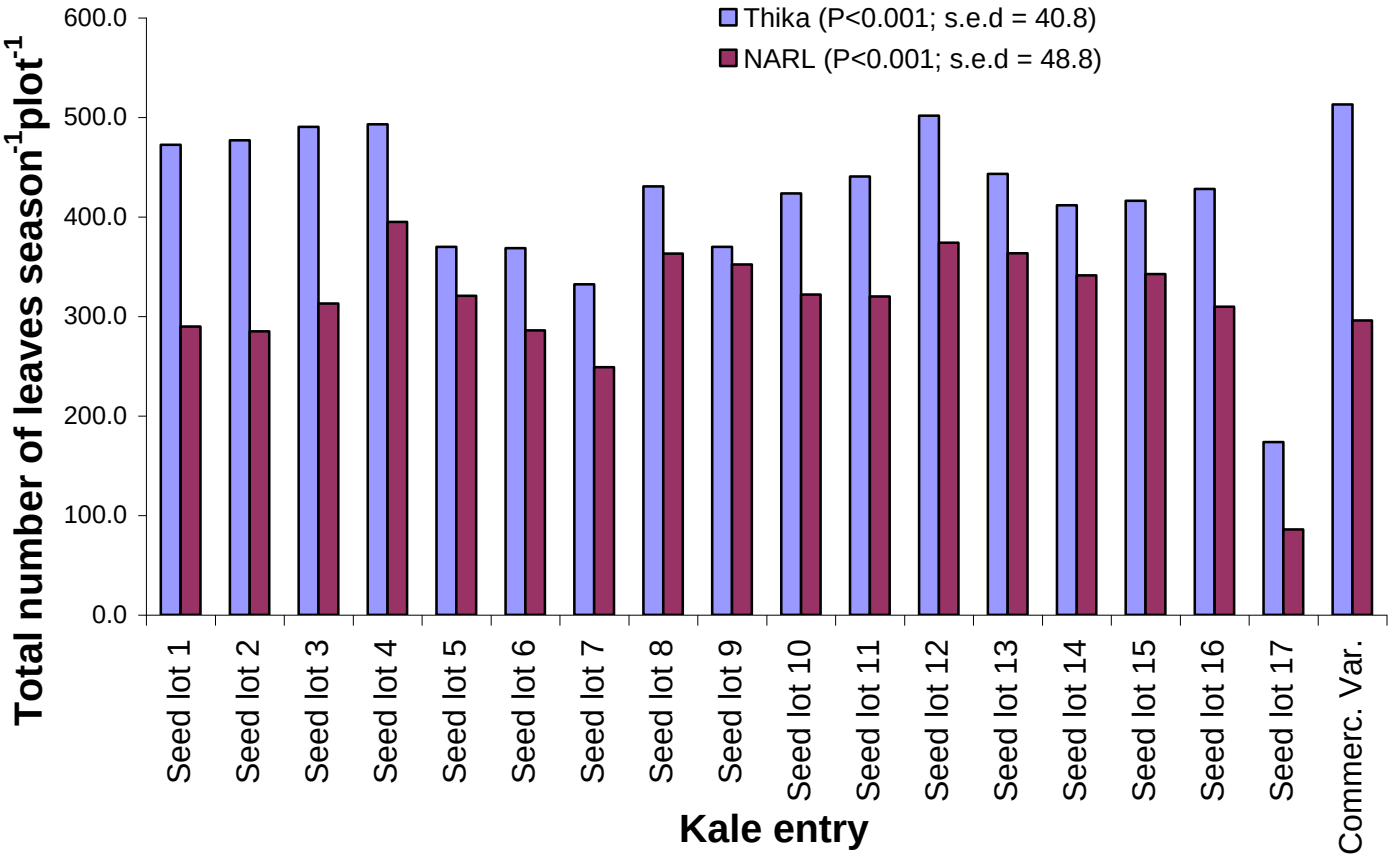
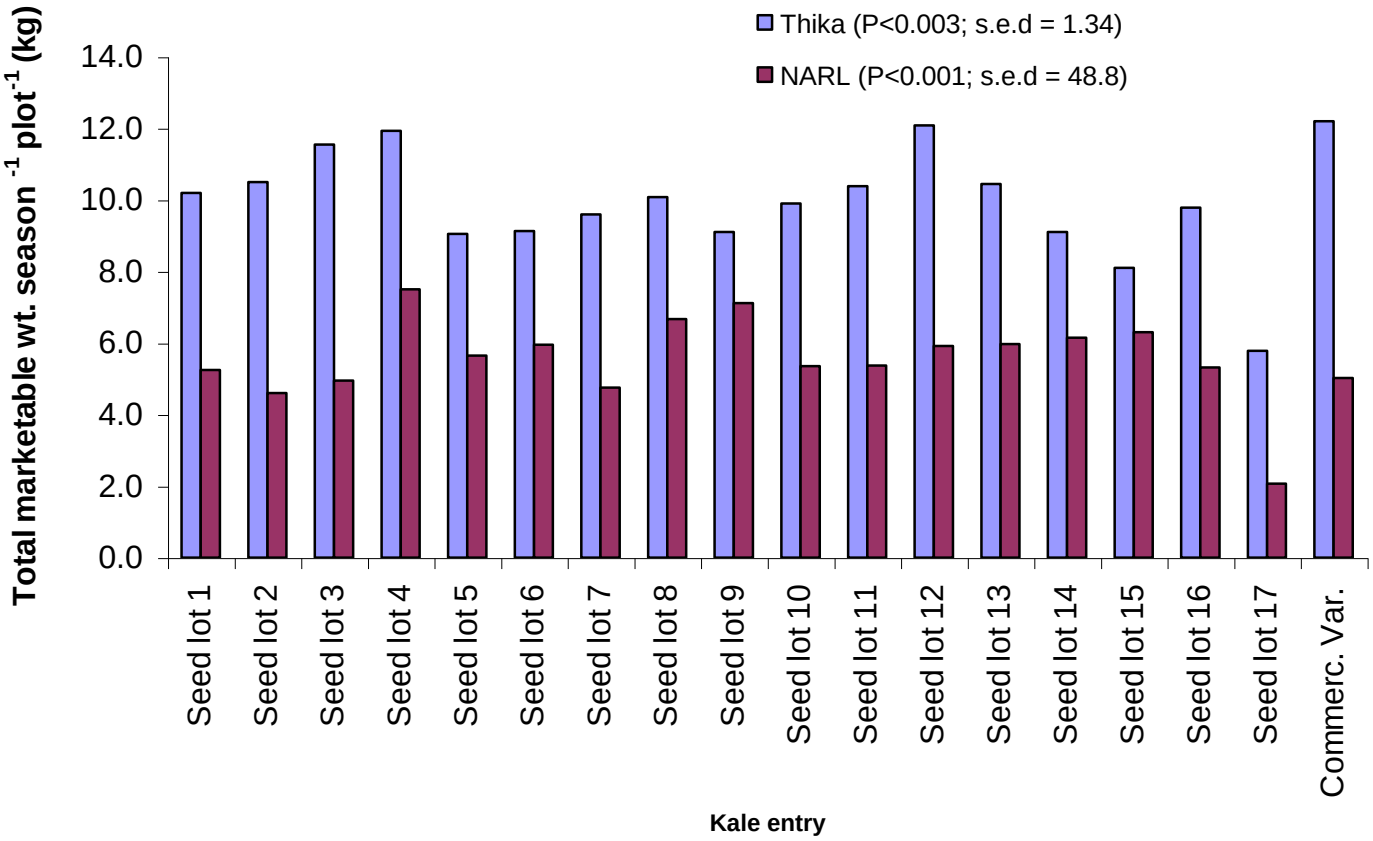


Fig. 3.3.3 Assessment of seed lots at NARL and Thika for total marketable weight of harvested leaves per plot over the season



Bad: Stunted growth, aphid infested and showing virus symptoms, leaf chlorosis, vein clearing, mottling and mosaic, leaf distortion, leaf puckering

Screening of subsequent seed

Once seed was planted in the design shown above, farmers and researchers assessed the nurseries for the criteria listed above. During the first sampling week none of the farmers could identify diseased plants because they were too small. During the second assessments only three farmers could identify disease symptoms.

Results are being analysed

Farmer field day

At the farmer field day two questions were frequently raised:

Q1 How can farmers identify healthy kale land race seeds from the market?

A1 It is very difficult to tell healthy from unhealthy seed either by colour or seed size, hence this research work.

Q2 How will farmers benefit from this research?

A2 Now that researchers have shown farmers how to select and harvest healthy seed using the criteria mentioned above the farmers can grow resistant/tolerant landraces with increased yield. This would also provide farmers with an opportunity to become agents of good seed by selling their surplus stock to markets.

Research Activity 4.1 PRA to assess farmer problems, perceptions and practices in relation to virus diseases and their aphid vectors

A more detailed report of this activity can be found in Njuki, 2001 (Appendix 4).

Results of PRA to assess farmer problems, perceptions and practices.

In Ruiru farmers were already members of a group, all farming along the Ruiru River and growing vegetables. In Athi River, there was no formal organisation of farmers and individual farmers were brought together to participate in the PRA and subsequent on-farm trials. All farmers were growing vegetables under irrigation.

Farmer wealth ranking

Described in results of Activity 2.3. Will be used in final PRA activity 4.2.

General problems and constraints in vegetable production and marketing.

Table 4.1.1 show the factors farmers consider to be important constraints on vegetable production. Diseases and pests were considered the most important constraint in both Ruiru and Athi River. Lack of finance and quality seeds were the second most important constraints in the two districts respectively.

Importantly, farmers in Athi River ranked lack of information on diseases and their control as the fourth most important constraint. Expensive inputs, especially pesticides were mentioned as a production constraint in Ruiru. This is of relevance to this project, as activities 2.1 and 2.2 have looked at non-chemical control methods for viral diseases.

Farmer ranking of common kale and cabbage varieties

Table 4.1.2 shows farmer assessments of different varieties of kale and cabbage. Thousand-headed variety of kale was considered more susceptible to diseases than the collard variety in both Athi River and Ruiru. Farmers had not observed any differences in susceptibility to diseases and pests among the cabbage varieties.

Farmers' perceptions of virus diseases

A pest and diseases symptoms calendar was drawn for both crops, Table 4.1.3, and was used to evaluate farmer perceptions of virus diseases and their control. In general, farmers in Ruiru were more knowledgeable about the symptoms and causes of insect pests and diseases than those in Athi River. This could be because the farmers in Ruiru were already members of a group and some group members have been for farmer training on various crops and crop management practices. Few farmers in Athi River had a clear perception of the relationship between disease carrying vectors and the disease symptoms they cause.

Athi River

Viral symptoms were identified as yellowing of leaves and rough leaf surface, these were attributed to too much water, too much manure and fertiliser or too much watering followed

Table 4.1.1 Vegetable production constraints considered important by farmers in Athi River and Ruiru

Rank	Athi River	Ruiru
1	Insect pests & diseases	Insect pests & diseases
2	Lack of quality seed	Lack of finance
3	Lack of credit/finance	Market flooding
4	Lack of information on diseases and methods of control	Transport to markets
5	Market flooding causing low prices	Soil nutrient deficiencies
6	Water pollution	Expensive inputs especially pesticides
7	Lack of experience in vegetable farming	Low quality of seed
8	Weather	Lack of technical information on vegetable growing
9	Wildlife menace	
10	Unavailability of water	

Table 4.1.2 Landraces and varieties of kale and cabbage considered priorities by farmers in Athi River and Ruiru

	Kale	Cabbage
Athi River	Collard Thousand Headed	Gloria Sugarloaf Drumhead Copenhagen Amukos
Ruiru	Collards Thousand Headed Kinale	Copenhagen Gloria Amigo Amukos Fortuna

Table 4.1.3 Disease calendar for kale in Athi River and Ruiru

Athi River					Ruiru					
Growth stage	Symptoms	Disease or pest (farmer)	Disease or pest (actual)	Control	Growth stage	Symptoms	Disease or pest (farmer)	Disease or pest (Actual)	Control	Most susceptible
Nursery	Whitish rusty leaves	Blight	Thousand headed	Ridomil Dithane Antracol	Nursery	Leaf perforations	Green or black caterpillars	Diamond Back Moth	Dimethoate Karate Marshal Diazinon Bulldock Fastac	Thousand headed
	Rotting of roots	Whitefly	Thousand headed	Karate Dimethoate		Fine leaf perforations	Green caterpillars	Diamond Back moth	Same as above	Thousand headed
	Drying on stem base	Cold	Thousand headed	As blight		Rotting stem	Cold		Ridomil copper	1000 headed
	Leaf perforation	Caterpillars Leaf hoppers	Thousand headed	Karate Dimethoate		Stunted growth	Low quality seed, poor soil		None	1000 headed
	Curling of leaves	Aphids	Thousand headed	Karate Dimethoate		Eaten leaves	Birds		Scare	All
						Wilting	Nutrient deficiency		None	
						Blight on leaves				
Seedbed	Drying of stem		Thousand headed		Seedbed	Small perforations	whitefly		Thuricide	Thousand headed
	Yellowing & drying of stem& roots		Thousand headed			Curling of leaves	Aphids		Dimethoate Karate Dry ash	Thousand headed
						Stem rot & drying	Caterpillars		Remove and kill	1000 headed
						Yellowish rough leaves	Cold		Ridomil Karate Dimethoate	Thousand headed
						Black leaf veins	Cold		Ridomil Karate Dimethoate Uproot	Thousand headed
						Whitish powder on underside of leaves	Fly (type not specified) Sunny conditions Insufficient water		Thioviate	Thousand headed
						Yellowing and drying of leaves	Mites		Dimethoate Karate	Thousand headed

by heavy rains. Some farmers also thought the problem started from the stem based on their observation of black and white strips on the stem of the affected plants. The farmers control these symptoms by removing affected leaves because then younger ones remain healthy. They attribute this to the fact that the plant is able to let water out through the injury that is left when the infected leaves are removed thus releasing excess water from the plant.

One farmer related the relationship between virus symptoms and aphids. He thought that the yellowing of leaves was due to aphids sucking water from the leaves, leaving the leaves yellow and finally causing drying up of the leaves.

Other farmers felt that the high nutrient levels associated with the yellowing would mean the plant would be too strong to be affected by aphids. Yellowing of leaves was also associated to blight and potassium deficiency by some farmers. The blighted leaves were believed to turn yellow when rained on.

Some farmers associated aphids with black rot believing that when the aphids settle on the cabbage before the head forms, the aphids are engulfed and this causes them to die and rot causing the whole cabbage head to rot.

Ruiru

Virus symptoms were identified as yellowing and curling of leaves and blackening or colouration of the leaf veins. The farmers associated yellowing of leaves to aphids, cold weather and mites. The virus symptoms were attributed to diamond back moth (DBM), aphids which suck sap from the leaves, low quality seeds, insufficient fertiliser (nutrient deficiency), lack of potassium, weeds which cover kale and prevent it from getting enough sunlight and the cold. The whitish powder on the leaves was linked to powdery mildew, which some farmers identified.

The farmers in Ruiru seemed to be more aware of other diseases, sometimes mentioning them by name, than they were aware of virus diseases. There is, however, some degree of recognition of aphids, which are the vectors for viral disease to the yellowing of leaves, one of the symptoms of viral diseases.

Evaluation of the effect of various symptoms on marketability, pricing and palatability of kale and cabbage

Other pests and diseases rather than viral diseases appear to be considered more critical to the marketability and prices of cabbages and kales. Yellowing and curling of leaves, which are symptoms of virus diseases, were evaluated as having moderate effects on the marketability, cost and palatability. This does not diminish the importance of controlling virus diseases due to the prevalence and the differing opinions of farmers. It may be more of a reflection of the market conditions in the two areas. Kale production in Athi River is higher and buyers have a wider selection to choose from and will therefore not buy any yellow leaves, while in Ruiru due to lower kale production there may be little choice for buyers in terms of general appearance of the kale and cabbages.

Control methods used by farmers

Most control methods are based on the application of pesticides. However, in identifying the production constraints, farmers in Athi River ranked lack of information on diseases and appropriate controls as fourth most important. Evidence suggests that there has been too much use of pesticides in the PU vegetable production system and there is need to focus more on cultural control methods that are more environmentally friendly and affordable to farmers.

Discussion

The results show that farmers consider diseases and pests as the most important constraint and that they associate aphids with virus symptoms. Increased knowledge of pests and diseases, as requested by farmers in Athi River, would be advantageous to farmers because even though they do associate aphids with virus symptoms they do not understand how the virus is transmitted and how best to control them. Farmers in Ruiru appeared to be more knowledgeable than those in Athi River, which suggests that farmer consortiums are an effective method for dissemination of knowledge rather than farmers being on their own, as in Athi River, where increased knowledge was identified as a requirement.

Contribution of Outputs to developmental impact

The anticipated outputs for activities completed in the project have been achieved as expected. The PRA activities have determined farmers' perception of virus diseases, how they currently control the diseases and how receptive they would be to the adoption of alternative methods. Farmers in Athi River and Ruiru considered and pests to be the major constraints of vegetable production in the PU region. Farmers in Athi River considered knowledge about diseases and pests to be an important method of combating this problem. This could be because farmers in Athi River are lone farmers so there is no method for dissemination of knowledge, whereas farmers in Ruiru work as a co-operative and generally had access to more knowledge than their counterparts in Athi River. This project has directly contributed to increasing the knowledge of farmers in terms of understanding how virus diseases spread and making them aware of the appropriate control methods available to them. The participatory approach of the project has also ensured that the management practices meet the demands of the farmers. The project has also stimulated farmers to form groups for dissemination of information through farmer field days etc.

The most common method of pest and disease control was by using chemical pesticides. Other projects in the PU vegetable cluster have identified that the farmers in general often use pesticide at a higher concentration than is necessary in the belief that more is better and they often use pesticides that are out of date and also spray too frequently. These practices have a negative impact on the environment and are particularly detrimental to the health of the farmer and the consumer. Pesticides are often not effective in controlling virus disease, for example, pesticides are useless in a scenario where virus disease has been spread through kale crops by the kale pickers through mechanical contact during harvest. This project has addressed the problem of inappropriate pesticide use by trialling alternative, low input, sustainable control methods of re-usable fleece and straw mulch to control virus disease in the nursery bed. Farmers in Athi River preferred to use their original method of dimethoate spray but were willing to use the fleece and straw treatments if they were more readily available and cheaper. The organic group of farmers in Kariguini favoured the mulch treatment and would like to try the fleece treatment again if it was more readily available. They also thought that the straw mulch would be more attractive if they could grow it themselves to make it cheaper, this is possible in Kariguini but not in Athi River. The results of this project show that the straw treatment is multi-purpose in that it has an impact on virus and aphid incidence. These low impact treatments could be combined with the biorational and pesticide initiatives of other CPP projects to produce a coherent integrated pest management programme.

The participation of farmers in the investigation of virus resistant germplasm has increased their awareness of the benefits of using resistant germplasm as a method of control. In the Kinale region farmers are able to grow and market their own kale seed due to the cold temperatures in the region, which effectively vernalise the plants encouraging them to flower. Farmers selected plants for seed based on length of time to flower and general health. A problem some farmers raised was the difficulty they have in finding good quality germplasm. In this project we have been working with the farmers to identify ways of improving seed quality by improving selection criteria. The identification of pest and disease resistant, good quality seed would increase yield, which would mean that less land would be required to grow the same amount of food. This would also reduce environmental degradation in the region and IPM strategies would reduce pesticide input.

The project has contributed to sustainable rural livelihoods in that the outputs will help farmers to produce their vegetable crops (for consumption and sale) in a safer, more effective and economic way. The benefits will include improved nutrition for whole families, reduction of risks from pesticide use and their consumption in the form of residues in produce, better cash returns from higher yields of better quality produce and an empowerment through agricultural knowledge which will help them to make informed choices on other cropping options. Dissemination activities included farmer meetings, workshops for extension staff and trainers and study tours for relevant researchers.

What further research is necessary?

Blackrot was identified as a serious problem during this project because it destroyed a screenhouse trial and was also an extensive problem in the samples collected throughout the project. Screenhouse experiments in the future would benefit the farmer by identifying the economic impact of blackrot on cabbages and investigating sustainable, low input control methods. Seed-borne *Xanthomonas campestris* is a serious threat to brassicas therefore research into management strategies in the field is urgently required.

The low input management strategies used in this project could have further impact by combining with the management of aphids and soil borne organisms such as root knot nematodes.

The close relationship between viruses and their vectors suggests that investigations into integrated control strategies would be appropriate. Future work on control of aphids would need to be combined with virus impact assessment.

Seed quality was identified as an area in which farmers required more research to be done. Quality of seed research could be combined with disease resistance but this may require a global effort including international partners such as AVRDC and HRI to ensure access to international seed collections.

Pathways whereby present and anticipated future outputs will impact on poverty alleviation or sustainable livelihoods

The results of the project have various established avenues for dissemination to intended beneficiaries. KARI works with the extension service and NGO's in dissemination of research results through demonstrations, field days and distribution of seed or information materials etc.

KARI and CABI have taken up and integrated project outputs into their activities as part of their training capability. It is also anticipated that CABI/KARI would participate in further stages to develop outputs.

Farmers at Kinale produce and market their own kale seed. Future research would identify how these markets could be expanded and promoted in a sustainable way.

The low input, sustainable management strategies identified in this project could be further developed to improve their effectiveness in reducing virus diseases and aphid vectors in brassicas. Promotional opportunities need to be exploited in the future to increase availability of these alternative methods.

Smallholder vegetable production provides an important source of employment, income generation and poverty alleviation for many households in rural areas. One of the major constraints in vegetable production systems remains, i.e., loss of crop yield and quality to pests and diseases. Smallholder farmers still rely heavily on the use of pesticides to reduce the damage from pests and diseases. However, excessive and inappropriate use of pesticides can result in residues in produce, induce resistance and be hazardous to human health and the environment, particularly to natural enemies and other beneficial organisms such as pollinators. By

developing an integrated pest management strategy for vegetable production, which reduces the reliance on pesticides, the volume and quality of vegetable production will be increased in a sustainable way in order to meet the requirements of an expanding urban population. A dependable supply of safe and affordable vegetables is an important requirement for dietary health, general health, especially low-income households. By ensuring the availability of alternative practices future research will decrease poverty and increase security of sustainable livelihoods.

Biometricians Signature

The projects named biometrician must sign off the Final Technical Report before it is submitted to CPP. This can either be done by the projects named biometrician signing in the space provided below, or by a letter or email from the named biometrician accompanying the Final Technical Report submitted to CPP. (Please note that NR International reserves the right to retain the final quarter's payment pending NR International's receipt and approval of the Final Technical Report, duly signed by the project's biometrician)

I confirm that the biometric issues have been adequately addressed in the Final Technical Report:

Signature:
Name (typed):
Position:
Date:

Appendices

Appendix 1

Survey of viruses of vegetable crops in the peri-urban production systems of Kenya – ZA0272

Summary

A visit was made to Kenya during 12-19 February 1999, to conduct a survey of virus diseases in vegetable production on farms around Nairobi to support pest management of vegetables/horticultural crops in the Peri-urban Production System in East Africa supported by the DFID Crop Protection Programme (CPP). In particular, to support the CPP research project ZA0080/1:*Pest Management for Horticultural Crops* led by Jerry Cooper, NRI and George Oduor, CABI respectively. Seventy-seven samples were collected from 18 different vegetable crops from 14 different farms. Possible virus symptoms of each sample were recorded in Kenya. On return to the UK each sample was inoculated to a range of host indicator plants as appropriate. Each sample was also tested for several known viruses using ELISA and samples of each crop were examined in the electron microscope (EM). After 7-10 days symptoms had developed in many of the indicator species and these were recorded. Further EM and ELISA was performed on samples from the indicator species. All original samples were stored in liquid nitrogen and samples of infected indicator species have been freeze-dried for future use. The diagnostic work is summarised in Tables 1, 2 and 3.

Cabbage, cauliflower and kale crops were found to be almost 100% infected with combinations of *Turnip mosaic virus* (TuMV), *Cauliflower mosaic virus* (CaMV) and *Beet western yellows virus* (BWYV). Pepper crops were 100% infected with combinations of *Pepper mild mottle virus* and potyviruses. As up to 10 different potyviruses can infect pepper further identification work is required. Cucumber and spinach crops were also severely affected by potyviruses, thought to be *Watermelon mosaic virus 2* (WMV-2) and *Beet mosaic potyvirus* (BtMV) respectively. Other crops which were virus-infected included celery, pumpkin and lettuce. Most of the viruses of importance are aphid-transmitted and the importance of vector control and other aspects of disease management are discussed.

Other objectives of this project were to provide advice to KARI and CABI staff on the collection of field samples and diagnosis of virus diseases and to make recommendations for the current demand-driven research needs in virology in vegetable/horticultural crops to the CPP Programme Management.

Background

Virus diseases are known to affect important vegetable crops in Kenya. Previous work by HRI, NRI and KARI revealed that TuMV and CaMV infect kale, but there is currently no detailed information about the distribution and relative importance of these viruses within Kenya. Other crops that are thought to be at risk from viruses are cabbage, spinach, squash, lettuce, tomatoes and onions. In order to prioritise research requirements and develop strategies for sustainable disease control, a survey of viruses of vegetable crops was conducted.

Initial meeting on 15 February at KARI NARL

I met Gilbert Kibata, George Oduor, Jackson Kung'u, Alex Kuria and Peter Karanja to discuss the purpose of my visit and plan the collection of field samples. We also discussed the current virology capability in Kenya.

I then briefly visited the CABI laboratories and offices at the ICRAF campus before embarking on a field visit to the Limuru district.

Kinale-Soko Mjinga Market in Lari division

Ten samples of kale seed produced by local farmers were purchased to investigate possible sources of disease resistance at a later time. We then visited 3 farms in the Kinale region. I was impressed by the good relationship with farmers abd Peter Karanja ensured the farmers understood what we were doing and showed them disease symptoms and any insect predators and parasitoids. The farmers were therefore friendly and co-operative.

Farm 1 Kinale

A 5 acre farm owned by Regina, mainly kale, cabbage and Irish potatoes. She had lost a crop of carrots due to the drought. There were many *Brevicoryne* aphids infesting the cabbage and kale. Crops had been sprayed with Ambush, but this had been ineffective, probably due to resistance. There was much evidence of virus infection, with yellow vein clearing symptoms in approx. 80% of the cabbage plants. Many aphids were parasitised, with evidence of mummified aphids on leaves. Three cabbage samples (cv Copenhagen) with vein clearing symptoms were collected (#1,2,3) and one kale sample with vein clearing (#4). There was also some *Alternaria* leaf spot on the cabbage. Broad bean volunteer plants were infested with *Aphis fabae*, but there was no evidence of virus. The cabbage samples were infected with TuMV and the kale with TuMV and BWYV.

Farm 2 Kinale

Nicholas Karugu's farm adjoining Farm 1. Kale and spinach (cv Fordhook Giant). The cultivar is dark green and very curly. There was little evidence of diseases apart from *Cercospora* leaf spot one spinach sample was collected to investigate a severe distortion and stunting symptom (#5). The spinach was infected with potyvirus, probably BtMV.

Farm 3 Kinale adjoining Farms 1 and 2

We noticed a cabbage (cv Gloria) plot with almost 100% virus symptoms, also with evidence of aphid feeding damage. Some plants had particularly severe vein clearing and were stunted and could have been infected at a very early stage. The yield of such plants was severely reduced and it seemed unlikely that they would form a head. Sample 6 was collected from a severely infected plant and was infected with BWYV, CaMV and TuMV.

Tuesday 16 February Field visit to Mwea District

Mwea is an important rice growing area as it has good water supplies. This also makes it ideal for peri-urban vegetable production as farmers can irrigate their fields. Vegetable crops in this area included green beans and tomatoes and crops were generally looking fairly healthy. However, there was extensive insecticide and fungicide application,with every crop visited having been sprayed that day or the day before. In several cases sprays had failed to control diamond back moth (DBM) and aphids, and at one organic farm better control had been achieved without any spray. This suggested that some pesticide resistance had developed and that sprays were killing beneficial parasitic organisms. Where there were high aphid populations (*Brevicoryne*) in kale crops there were always high levels of virus infection, but when aphids were controlled either with or without sprays, there was little or no virus problem.

Farm 4 Wanguru

We visited a demonstration farm run by the Chrisitian Community Services. The manager, Mary Gichobi showed us irrigated crops of beans, peas, tomatoes, cabbage and maize, as well as a small organic crop of cabbage, groundnuts, tomatoes and chilli. The cabbage had been sprayed with Karate, but this had not been effective as the whole crop was severely affected by DBM. It was unlikely that the crop would yield any cabbages as no heads were forming. Also, there was no sign of beneficial parasitoids on the cabbage plants. Samples (#7 and #8) were taken, and whilst there were no obvious virus symptoms due to DBM damage, #7 was infected with BWV and #8 with BWYV and TuMV. The cabbages were inter-planted with

peas that had yellow vein clearing symptoms (#9) and although potyvirus was detected using ELISA, no virus was isolated. Tomatoes were affected by bacterial wilt, late blight and early blight and there was also evidence of root knot nematodes but no virus symptoms. French beans had no diseases symptoms but a crop or dwarf beans were severely affected by angular leaf spot and bean rust. In the organic plot, cabbages had not been sprayed and were less severely affected by DBM. There was also evidence of beneficial parasitoids. Groundnuts had thrips feeding damage, mealy bugs and possible virus symptoms of chlorotic spots (#10) and although potyvirus was detected using ELISA, no virus was isolated.

Farm 5 Wanguru

A tomato crop of approximately 0.5 acres had recently been heavily sprayed with M45 and pesticide residue covered the leaves. The main problems were bacterial wilt and root knot nematodes, with possible *Fusarium* and *Verticillium* infections. Some plants were also stunted and distorted (samples #11 and 12) but no virus was detected.

Farm 6 Michael's farm at Wanguru

This farm supplies kale (cv Collards) for the whole village which is inter-planted with maize. There was little DBM damage and the kale had been sprayed, but not with Karate. Many beneficial parasitoids were present. There was a high incidence of virus symptoms (c.80%) with severe *Brevicoryne* infestations. Virus symptoms ranged from vein clearing (#15) to chlorotic spots (#13, 14 & 16). Some plants were very severely affected and stunted. These four samples were infected with combinations of BWYV, CaMV and TuMV. Some plants with bluer foliage appeared to be resistant. A *Datura stramonium* plant had a possible chlorotic symptom (sample #17) but no virus was detected. Indicator plants (*Brassica perviridis*) inoculated with sample 16 exhibited very severe symptoms. A field of tomatoes nearby had severe bacterial wilt but there was no evidence of virus infection.

Wednesday 17 February Field surveys at Athi River

Farm 7 Jane Mutsya's farm

About 5 acres of French beans at different stages of maturity were being grown for export; also some red onions. Older bean crops were severely affected by bean rust, although they had been sprayed for rust. Sprays for red spider mite had been effective. There were several yellow patches in a younger crop of beans, which was thought to be due to nutritional deficiencies. Samples were taken for checking (#18-22), although no virus was detected. The

red onions (cv Red Creole) had thrips feeding damage and some plants had yellow streaks so samples were taken (#23 & 24) but no virus was detected.

Farm 8 Joshua Nzive Mulwa's farm

Mainly kale and sweet pepper crops, with a few aubergines. The peppers had been planted 12 months previously and were 100% infected with viruses. The farmer reported that symptoms first appeared approximately 6 months after planting. Plants were stunted with leaf and fruit distortion and leaf mosaic (samples #25-28) and all contained potyviruses, although samples also tested positive for tomato mosaic virus (ToMV) in ELISA. There can be up to 10 different potyviruses infecting sweet pepper so further characterisation will be required to identify viruses present in Kenya. There were very severe symptoms in indicator plants inoculated with these samples. The kale crop was also severely affected by virus, with symptoms ranging from severe yellow mosaic to vein clearing (samples #29-32) and most samples were affected by BWYV, CaMV and TuMV. *B. perviridis* indicator plants had very severe symptoms after inoculation with these samples. An aubergine crop was severely affected by red spider mite but there were no signs of pathogens.

Farm 8a Joshua Nzive Mulwa's farm

Approximately 1km away from Farm 8 there was a large crop of cabbage inter-planted with sweet pepper. Cabbage (cv Gloria) was 100% infected with virus (sample #33 was infected with BWYV), but many cabbages had formed good heads.

The sweet peppers were also 100% infected with potyvirus (sample #35) and an aubergine plant with yellow leaves was sampled (#34) and found to be infected with potyvirus and ToMV.

Farm 9 Simon Mangeli's farm

A wide range of vegetable crops including French beans for export, kale, pumpkin, cowpea and spinach. All crops had possible virus symptoms: yellow leaf blisters on the pumpkin leaves (#37 – no virus detected), mosaic symtpoms on the cowpeas (#36, 38 & 39 – no virus detected). Spinach had severe chlorosis and distortion (#40 & 41 – potyvirus), French beans had chlorotic spots and distortion (#42-44 – no virus detected) and 100% of kale plants had virus symptoms (#45 & 46 – BWYV, CaMV and TuMV).

Thursday 18 February Field surveys around Nyathona District

Farm 10 Mr Cheche's farm, Wangigi

A kale crop growing alongside a crop of spinach, both with100% virus infection. Kale symptoms were mosaic and vein clearing (#50 & 51 – BWYV and TuMV). The kale also had a *Brevicoryne* problem. Spinach had severe chlorotic mottle and stunting symptoms (#47 & 48 – BWYV) and severe yellowing (#49 – TuMV). Another spinach crop also had a severe *Cercospora* problem. A lettuce crop appeared to have extensive vein clearing symptoms, however this could have been varietal. Other symptoms were leaf blistering (#52 & 53) but only BWYV was detected in lettuce. The lettuce crop was also severely affected by *Sclerotinia* (30%). Further down the calley (10a), a large spinach field was >80% affected by chlorotic mottle symptoms (#54 & 55 – potyvirus). Another kale crop was 100% affected by virus (#56 – CaMV and BWYV). French beans were affected by *Aphis fabae* and had mosaic, green vein banding and distortion (#57 & 58) caused by potyvirus, although no virus was isolated.

Farm 11 Mrs Gathura

A number of spinach plots, all with >80% chlorotic mottle symptoms. Mostly the younger leaves were affected and Mrs Gatura complained that the new leaves were very small, distorted and not marketable (#60 & 61 – potyvirus). There were also severla coriander crops, one of which had yellowing and reddening of leaf margins (#59 – no virus dtected). A carrot crop looked very healthy. A cabbage crop had 100% virus (#63 – BWYV) and was also affected by black rot. An adjoining cauliflower crop was 50-60% affected by virus (#64 – BWYV and CaMV). A small squash crop had yellow blistering on the leaves (#62 – no virus detected).

Farm 12 Mungai Kuria's farm

A cucumber crop with 30-40% of plants exhibiting mosaic symptoms in the younger leaves (#65, 66 & 67 – potyvirus, probably WMV-2).

Farm 13 David Karugu's farm

A cucumber crop with approx. 80% of plants exhibiting severe mosaic and green vein clearing symptoms in younger leaves (#69, 70 & 71 – potyvirus, probably WMV-2). Cucumber plants were also severely stunted and some fruit were distorted. Many plants were unlikely to produce any fruit. Kale crops were 100% affected by virus, cabbage approx. 70% affected and cauliflower was approx. 70% affected by vein clearing (#68 – BWYV and TuMV). Kale seed beds were approx. 10% affected by virus, with a higher incidence in older

seed beds which had also been affected by aphids. There was very little DBM damage (high insecticide input).

Farm 14 John Kbiaru's farm

Shallots exhibited white tip symptoms but there were no virus symptoms. Leeks had thrips damage but no virus symptoms and sweet peppers were 100% affected by severe mosaic (#75 & 76 – potyvirus). Approx. 70% of the celery crop had severe yellowing of the leaf margin (#72 – 74 – *Celery mosaic virus*). Approximately 80% of lettuce crops were affected by *Sclerotinia* and some plants had possible vein clearing symptoms (#77 – no virus detected). There were many *Brevicoryne* aphids on the lettuce. Kale crops were approx. 70% affected by virus.

Conclusions

- Cabbage, cauliflower abd kale crops were virtually 100% infected with combinations of BWYV, CaMV and TuMV. Crop losses are difficult to estimate but must be considerable as virus infection causes stunting of plants and reduced leaf are (kale) or head production (cabbage). All three ciruses are transmitted by several aphid species and are not transmitted in seed. However, from observations and previous experience BWYV was not considered to be causing significant symptoms or losses.
- The key to control of the *Brassica* viruses is effective vector control in combination with identification and development of genetic resistance. There is no genetic resistance in commercial *Brassica oleracea*, however it was noted that there was some phenotypic variation in local cultivars of kale and differences in susceptibility to viruses in the field. These cultivars are probably land races and should be screened for potential sources of resistance. Seed was collected from 10 land races of kale from the Kinale region, an area where farmers save seed for planting.
- For evaluation of genetic resistance in land races of kale it is necessary to determine pathotype diversity. This is possible for TuMV as differential cultivars have been identified and monoclonal antibodies produced at HRI. There is currently no system for pathotyping CaMV, but local *Brassica* lines could be screened to examine CaMV variation. Isolates of CaMV and TuMV from the present study have been preserved for future use.
- Control of aphids as part of an IPM strategy is part of project ZA0080/1: *Pest Management for Horticultural Crops* led by J Cooper, NRI and G Oduor, CABI Kenya respectively. Future experiments should include a component to investigate the efficacy of treatments for control of viruses, as well as aphid vectors.

- Pepper crops were 100% infected with combinations of *Pepper mild mottle virus* and potyviruses. As up to 10 different potyviruses can infect pepper further identification work is required. Viruses of pepper and chilli are very damaging and can cause complete crop failure. However, there are sources of resistance to several viruses in *Capsicum anuum* that should be evaluated once the viruses have been identified. Also, some viruses are seed-transmitted so improvements in seed health management would reduce incidence of virus diseases.
- Cucumber and spinach crops were also severely affected y potyviruses, which were probably WMV-2 and BtMV respectively. Neither virus is seed-transmitted but both are transmitted by several species of aphid so vector control is important.
- Other crops that were infected by viruses were celery, pumpkin and lettuce. In each case the viruses were aphid transmitted so the importance on management if aphids is emphasised again.
- KARI and CABI staff were advised on the collection of field samples and diagnosis of virus diseases and materials were left do that samples could be collected and sent to HRI, Wellesbourne for diagnosis at a later time. It was clear that the capacity for virus identification is extremely limited. The virology laboratory at KARI (NARL) had an ELISA plate reader and PCR thermocycler but this equipment did not appear to be in use due to problems in obtaining and maintaining reagents. The development of robust and cheap virus diagnostic techniques where reagents do not require refrigeration would make a significant impact to virus research in Kenya. At HRI the development of lateral flow technology for pathogen detection in a simple "pregnancy test" format could be utilised for detection of viruses in Kenya.
- A confidential short report on institutional capabilities and facilities is provided separately.

Recommendations for the current research needs in virology in vegetable/horticulture crops to the CPP Programme Management

***Brassica* viruses**

A Vector control

Objective: To determine the effect of vector control on virus incidence

- Include a component to determine the incidence of viruses (BWYV, CaMV and TuMV) in aphid control trials in project ZA0080/1: *Pest Management for Horticultural Crops* led by

J Cooper, NRI and G Oduor, CABI Kenya. Future experiments should determine the efficacy of treatments for control of viruses, as well as their aphid vectors.

B **Genetic resistance**

Objective: To assess pathogen diversity and identify sources of host resistance

- Determine pathotype diversity of Kenyan isolates of TuMV collected in this survey using different cultivars and monoclonal antibodies already available at HRI.
- Screen local cultivars and land races of kale collected in the present survey and evaluate for resistance to Kenyan isolates of TuMV and CaMV.

C **Diagnostics**

Objective: To develop appropriate diagnostics methods for local use

- The development of robust and cheap virus diagnostic techniques for TuMV using lateral flow technology. This technology could then be adapted for other viruses of importance.

D **Disease management**

Objective: To protect seed beds from sources of virus infection

- Investigate management methods to protect *Brassica* seed beds from virus infection *e.g.* mulches, fleece, straw etc.

1. Pepper viruses

Objective To idemtify viruses infecting pepper and develop disease control strategies

- Identify and characterise potyviruses infecting sweet pepper using antibodies and molecular diagnostic techniques.
- Determine the incidence of PMMV in sweet pepper seed and evaluate seed treatments to eradicate PMMV from seed.
- Screen local cultivars and land races of pepper collected in the present survey and evaluate for resistance to kenyan isolates of PMMV and potyviruses from pepper.

2. Viruses of other crops

Objective: To determine the effect of vector control on virus incidence

- Spinach. Include a component to determine the incidence of viruses (BtMV in spinach) in aphid control trials in project ZA0080/1: *Pest Management for Horticultural Crops* led by J Cooper, NRI and G Oduor, CABI Kenya. Future experiments should determine the efficacy of treatments for control of viruses, as well as their aphid vectors.

- Cucumber crops were severely affected by a potyvirus, which was probably WMV-2. This virus is not seed-transmitted but is transmitted by several species of aphid so vector control is important in this crop.
- Other crops that were infected by viruses to a minor extent were celery, pumpkin and lettuce. In each case the viruses were aphid transmitted so the importance on management of aphids is important.

Appendix 2
Mechanical Inoculation
Materials
Inoculation buffer – 1% K_2HPO_4, 0.1% Na_2SO_3
Carborundum (300 mesh)
Muslin

Method
Virus inocula were prepared by grinding systemically infected leaves in cold inoculation buffer. Leaves of test plants were dusted with carborundum and then rubbed with a muslin pad saturated with virus inoculum.

Turnip mosaic virus Plate Trapped Antigen Enzyme Linked Immunosorbent Assay (PTA – ELISA) Test

Materials
Coating Buffer (Na_2CO_3, 1.6g.l^{-1}; $NaHCO_3$, 30g.l^{-1})
Phosphate buffered saline ($Na_2HPO_4.12H_20$, 2.9g,l^{-1}; KH_2PO_4, 0.2g.l^{-1}; NaCl, 8g.l^{-1}; KCl, 0.2g.l^{-1}) containing 0.5% Tween-20 (PBS-T, pH 7.3)
EMA 67 (HRI, Primary antibody)
Goat anti-mouse conjugated to alkaline phosphatase (Sigma A-3562, Secondary antibody)
Substrate buffer (diethanolamine, 97ml.l^{-1}, dH_20, pH9.8)

Titertek Multiskan MCC/340 plate reader
96 well ELISA plate

Method
Samples were ground and the sap was diluted 1:10 in coating buffer. 100µl of the diluted sap was loaded into duplicate wells on a microtitre plate. Positive and negative controls were loaded onto each ELISA plate every time ELISA tests were done. The loaded microtitre plate was stored at 4°C overnight.

After the overnight incubation the plates were washed three times for three minutes in PBS-T. The plates were then coated with the primary antibody, EMA 67, diluted 1/2500 in PBS-T containing 0.05% BSA (100µl per well) and incubated at room temperature for 2 hours. After incubation, the plates were washed in PBS-T (as described previously) and coated with the secondary antibody conjugate, goat anti-mouse IgG conjugated to alkaline phosphatase, diluted 1/5000 in PBS-T containing 0.05% BSA (100µl per well). The plates were incubated

for a further 2 hours at room temperature. After incubation the plates were washed (as described previously) and the colour reaction developed by adding 100µl per well substrate buffer to each well. The reactions were read with a plate reader at an absorbance of 405nm. In all ELISA tests the sample readings were compared to the healthy control reading and a reaction was considered positive if the reading was twice that of a healthy.

Cauliflower mosaic virus (CaMV) Double Antibody Sandwich ELISA test ***(used 03/2000 – 04/2001)***

Materials

Freeze-dried γ-globulin (1mg.ml^{-1}, HRI)

Antibody conjugate (HRI)

Sterile distilled water (SDW)

Coating buffer (Na_2CO_3, 1.6g.l^{-1}; $NaHCO_3$, 30g.l^{-1})

Phosphate buffered saline ($Na_2HPO_4.12H_2O$, 2.9g.l^{-1}; KH_2PO_4, 0.2g.l^{-1}; NaCl, 8g.l^{-1}; KCl, 0.2g.l^{-1}) containing 0.5% Tween-20 (PBS-T, pH 7.3)

Grinding buffer (100ml PBS-T; 2g polyvinylpyrollidone (PVP))

Bovine serum albumin (BSA)

Substrate buffer (diethanolamine, 97ml.l^{-1}, dH_20, pH9.8)

Method

Freeze-dried γ-globulin was resuspended in 100µl SDW and then diluted to a final concentration of 1µg.ml^{-1} with coating buffer. ELISA plates were coated with 100µl diluted γ-globulin per well and incubated at 35°C for 3 hours. Test leaves were ground in grinding buffer (1ml buffer per 1g sample) and stored on ice until required. The ELISA plates were washed in PBS-T as described previously. Samples were loaded into duplicate wells on the ELISA plates (100µl per well) and stored overnight at 4°C.

The plates were washed with PBS-T as described previously. Conjugate was diluted to a final concentration of 1µg.ml^{-1} and 100µl added per well. The plates were incubated for 5 hours at 35°C. The plates were then washed as described previously with PBS-T and 100µl substrate buffer added per well. The plates were read at 405nm using a plate reader after 1 hour and again the next morning. A positive reaction was taken as twice the mean healthy control.

CaMV PTA-ELISA test (used 04/2001 – present)

Materials
Coating Buffer (Na_2CO_3, 1.6g.l^{-1}; $NaHCO_3$, 30g.l^{-1})

Phosphate buffered saline ($Na_2HPO_4.12H_2O$, 2.9g,l^{-1}; KH_2PO_4, 0.2g.l^{-1}; NaCl, 8g.l^{-1}; KCl, 0.2g.l^{-1}) containing 0.5% Tween-20 (PBS-T, pH 7.3)

Bovine serum albumin (BSA)

EMA 95 (HRI, Primary antibody)

Goat anti-mouse conjugated to alkaline phosphatase (Sigma A-3562, Secondary antibody)

Substrate buffer (diethanolamine, 97ml.l^{-1}, dH_20, pH9.8)

Titertek Multiskan MCC/340 plate reader

96 well ELISA plate

Method
As for TuMV PTA-ELISA except that the primary antibody used was EMA 195, diluted 1/1000 in PBS-T + 0.05% BSA.

Potyvirus PTA-ELISA test

Materials
Coating Buffer (Na_2CO_3, 1.6g.l^{-1}; $NaHCO_3$, 30g.l^{-1})

Phosphate buffered saline ($Na_2HPO_4.12H_2O$, 2.9g,l^{-1}; KH_2PO_4, 0.2g.l^{-1}; NaCl, 8g.l^{-1}; KCl, 0.2g.l^{-1}) containing 0.5% Tween-20 (PBS-T, pH 7.3)

Bovine serum albumin (BSA)

Anti-Poty (Agdia SRA 27200/0500, Primary antibody)

Goat anti-mouse conjugated to alkaline phosphatase (Sigma A-3562, Secondary antibody)

Substrate buffer (diethanolamine, 97ml.l^{-1}, dH_20, pH9.8)

Titertek Multiskan MCC/340 plate reader

96 well ELISA plate

Method
As for TuMV PTA-ELISA except that the primary antibody used was Agdia anti-Poty, diluted 1/200 in PBS-T + 0.05% BSA.

Potyvirus RT-PCR (Pappu et al.*, 1993)*

RNA Extraction
RNA extracted from infected leaf material using Qiagen Rneasy kit.

RT-PCR and amplification
Extracted RNA was used as the template. The reaction was a two-stage protocol and included 400μM of each dNTP, 75 pmol of each primer (forward primer was CN48F, reverse primers were CN47R, CN54R and CN55R), 10U of RNAsin, 10mM DTT, 50mM KCl, 10mM Tris-HCl pH 8.8, 0.1% Triton X-100, 2.5mM $MgCl_2$, 15 units of superscript, 2.5U of *Taq* Polymerase and 20μl of template in a total reaction volume of 100μl.

The template was heated at 70°C for 3 minutes before adding to the reaction mix. First strand cDNA synthesis was accomplished by incubation at 42°C for 30 minutes before the amplification reaction. The amplification conditions used were as follows: 94°C, 2 minutes; 42°C, 2 minutes; 72°C, 2 minutes (40 cycles) followed by one cycle of elongation at 72°C for 10 minutes.

The PCR products were visualised on a 2% TBE agarose gel. The expected product size was 700 bp.

PCR clean up
The PCR products were at 700 bp but there was a faint product at 400 bp which was removed using a Qiaquick PCR product purification kit.

Cloning and sequencing of PCR product
PCR product was cloned using the Amersham pMOS Blue blunt ended cloning kit. 1μg PCR product was sent to SequiServe (Dr Willi Metzger) for sequencing. Used NCBI database BLAST programme to obtain comparisons with other sequences.

Appendix 3

Sample	Farm	Location	Host	Symptoms	Insect	CaMV	TuMV
1	Farm 1	Nyathona	Kale	lc, sc, sm	DBM, BB	CaMV	-
2	Farm 1	Nyathona	Kale	sc		CaMV	-
3	Farm 1	Nyathona	Kale	sc	BB	CaMV	-
4	Farm 1	Nyathona	Kale	sc	BB	CaMV	-
5	Farm 1	Nyathona	Cabbage	sc		CaMV	-
6	Farm 2	Nyathona	Spinach	sc, sm		CaMV	-
7	Farm 2	Nyathona	Spinach	sc		CaMV	-
8	Farm 2	Nyathona	Kale	sc		CaMV	-
9	Farm 2	Nyathona	Kale	sc		CaMV	-
10	Farm 3	Nyathona	Kale	sc, sm	BB	CaMV	-
11	Farm 3	Nyathona	Kale	lc, sc, sm		-	TuMV
12	Farm 3	Nyathona	Kale	sc, sm, sn		-	TuMV
13	Farm 3	Nyathona	Cabbage	sc	BB	-	TuMV
15	Farm 4	Nyathona	Cabbage	sc		CaMV	-
16	Farm 4	Nyathona	Cabbage	sc	BB	-	-
17	Farm 4	Nyathona	Kale	sc	BB	CaMV	-
18	Farm 4	Nyathona	Kale	sc, sm		-	TuMV
19	Farm 4	Nyathona	Kale	sc	BB	-	-
20	Farm 5	Kinale	Cabbage	sc	DBM, BB	CaMV	TuMV?
21	Farm 5	Kinale	Cabbage	sc		-	-
22	Farm 5	Kinale	Kale	sc		CaMV	-
23	Farm 5	Kinale	Kale	purpling, sc	BB	CaMV	-
24	Farm 5	Kinale	Kale	sc, sm		CaMV	-
25	Farm 5	Kinale	Kale	sc	BB	CaMV	-
26	Farm 5	Kinale	Kale	sc	BB	CaMV	-
27	Farm 6	Kinale	Cabbage	sc		CaMV	TuMV?
28	Farm 6	Kinale	Cabbage	sc		-	-
29	Farm 6	Kinale	Cabbage	purpling, sc		-	-
30	Farm 6	Kinale	Kale	yellowing, sc	BB	CaMV	-
31	Farm 6	Kinale	Kale	sc	DBM	CaMV	TuMV?
32	Farm 6	Kinale	Kale	sc		CaMV	-
33	Farm 6	Kinale	Kale	sc	BB	CaMV	-
34	Farm 7	Kinale	Cabbage	sc		CaMV	-

Sample	Farm	Location	Host	Symptoms	Insect	CaMV	TuMV
35	Farm 7	Kinale	Kale	sc	DBM	CaMV	-
36	Farm 7	Kinale	Cabbage	sc	BB	-	-
37	Farm8	Mwea, (Kimbamba)	Kale	sc	DBM	CaMV	TuMV?
38	Farm8	Mwea, (Kimbamba)	Kale	sc, sm	DBM	-	-
39	Farm 9	Mwea	Kale	sc	DBM	-	-
40	Farm 9	Mwea	Kale	yellowing, sc		CaMV	-
41	Farm 10	Embu	Cabbage	sc		CaMV	-
42	Farm 10	Embu	Cabbage	sc	BB	-	-
43	Farm 10	Embu	Kale	sc		CaMV	-
44	Farm 10	Embu	Kale	sc	DBM	CaMV	-
45	Farm 11	Embu	Kale	sc	BB	CaMV	-
46	Farm 11	Embu	Cabbage	sc		CaMV	-
47	Farm 12	Mwea West (Riambogo)	Cabbage	yellowing, sc	DBM, BB, LP	CaMV	-
48	Farm 12	Mwea West (Riambogo)	Kale	sc, sm		-	TuMV
49	Farm 12	Mwea West (Riambogo)	Kale	yellowing, sc		CaMV	-
51	Farm13	Giachia (Ndia)	Kale	sc		CaMV	-
52	Farm 14	Kaitheri	Kale	sc	DBM, BB, MP, LP	CaMV	-
53	Farm 14	Kaitheri	Kale	sc	DBM, BB, MP, LP	CaMV	-
54	Farm 15	Mathira (Nyeri)	Kale	sc, sm		CaMV	-
55	Farm 15	Mathira (Nyeri)	Kale	sc	BB, MP	CaMV	-
56	Farm 15	Mathira (Nyeri)	Kale	sc	BB, MP	CaMV	-
57	Farm 15	Mathira (Nyeri)	Kale	purpling		CaMV	-
58	Farm 16	Karatina	Kale	sc	BB, DBM	CaMV	-
59	Farm 16	Karatina	Kale	sc	BB, DBM	CaMV	-
60	Farm 16	Karatina	Cabbage	sc	BB, LP, DBM	CaMV	-
61	Farm 16	Karatina	Cabbage	yellowing, sc	BB, LP, MP	-	-
62	Farm 17	Guti (Karatina-Mathira)	Cabbage	sc	DBM, LP	-	-
64	Farm 17	Guti (Karatina-Mathira)	Cabbage	sc	BB	CaMV	-
65	Farm 18	Giti (Karatina-Mathira)	Cabbage	sc		-	-
66	Farm 18	Giti (Karatina-Mathira)	Cabbage	sc	DBM	CaMV	TuMV?
67	Farm 19	Kamuyu-Nyeri	Cabbage	sc	DBM	-	-
68	Farm 19	Kamuyu-Nyeri	Cabbage	sc	DBM	-	TuMV?
70	Farm 20	Kibirigwi	Kale	sc	BB, DBM	CaMV	-
71	Farm 20	Kibirigwi	Kale	yellowing, sc		-	-

Sample	Farm	Location	Host	Symptoms	Insect	CaMV	TuMV
72	Farm 20	Kibirigwi	Kale	sc		-	-
73	Farm 20	Kibirigwi	Kale	sc	BB	CaMV	-
74	Farm 21	Kibirigwi	Kale	sc	MP	CaMV	-
75	Farm 21	Kibirigwi	Kale	sc	MP	CaMV	-
76	Farm 22	Kibirigwi	Kale	sc	MP	CaMV	-
77	Farm 22	Kibirigwi	Kale	sc	LP	CaMV	-
78	Farm 23	Mukuha	Kale	sc		CaMV	-
79	Farm 23	Mukuha	Cabbage	sc	MP, DBM	CaMV	-
81	Farm 24	?	Kale	sc	DBM	CaMV	-
82	Farm 24	?	Kale	purpling	MP	CaMV	-
83	Farm 24	?	Cabbage	yellowing	MP, BB	CaMV	-
84	Farm 24	?	Cabbage	sc		CaMV	-
85	Farm 25	Gatanga	Kale	sc, sm		CaMV	-
86	Farm 25	Gatanga	Kale	yellowing, purpling, sc		CaMV	-
89	Farm 26	Karuri (Mangu)	Kale	none		-	TuMV
90	Farm 26	Karuri (Mangu)	Kale	purpling, sc	BB	CaMV	-
91	Farm 26	Karuri (Mangu)	Cabbage	sc	BB	CaMV	-
92	Farm 27	Ngong'	Kale	sc		CaMV	-
93	Farm 27	Ngong'	Kale	purpling, sc	DBM	CaMV	TuMV
94	Farm 27	Ngong'	Kale	sc		-	-
95	Farm 27	Ngong'	Kale	sc		CaMV	-
96	Farm 28	Kiserian	Kale	sc		-	-
97	Farm 28	Kiserian	Kale	sc		CaMV	TuMV
98	Farm 28	Kiserian	Kale	sc	DBM	CaMV	-
99	Farm 29	Kiserian	Kale	sc		CaMV	-
100	Farm 29	Kiserian	Kale	sc	BB	-	-
101	Farm 29	Kiserian	Kale	sc			
102	Farm 30	Athi River	Kale	sc		CaMV	TuMV
103	Farm 2	Nyathona	Cabbage	purpling, sc	BB		
104	Farm 2	Nyathona	Cauliflower	sc			
105	Farm 2	Nyathona	Cauliflower	sc, sm			
106	Farm 2	Nyathona	Cauliflower	sc, sn		-	-
107	Farm 2	Nyathona	Cauliflower	sc, sn	BB	-	-
108	Farm 3	Nyathona	Cauliflower	sc		-	-
109	Farm 3	Nyathona	Cauliflower	sc			

Sample	Farm	Location	Host	Symptoms	Insect	CaMV	TuMV
110	Farm 3	Nyathona	Cauliflower	sc		-	-
111	Farm 3	Nyathona	Kale	none			
112	Farm 3	Nyathona	Kale	none			
113	Farm 31	Nyathona	Cauliflower	sc			
114	Farm 31	Nyathona	Cauliflower	sc	BB		
115	Farm 31	Nyathona	Cauliflower	sc		-	-
116	Farm 31	Nyathona	Cauliflower	sc		-	-
117	Farm 31	Nyathona	Cauliflower	sm	BB	-	-
118	Mrs Gatura	Nyathona	Spinach, 7 mth	sm			
119	Mrs Gatura	Nyathona	Spinach, 7 mth	sm	BB, MP		
120	Mrs Gatura	Nyathona	Spinach, 7 mth	sm	BB, MP		
121	Mrs Gatura	Nyathona	Spinach, 7 mth	sm	BB, MP		
122	Mrs Gatura	Nyathona	Spinach, 7 mth	sm	BB, MP		
123	Mrs Gatura	Nyathona	Spinach, 3.5 mth	sc, sm			
124	Mrs Gatura	Nyathona	Spinach, 3.5 mth	sc, sm			
125	Mrs Gatura	Nyathona	Spinach, 3.5 mth	sm			
126	Mrs Gatura	Nyathona	Spinach, 3.5 mth	sm			
127	Mrs Gatura	Nyathona	Spinach, 3.5 mth	sc, sm			
128	Mr Karugu	Nyathona	Spinach, 2 mth	distortion	BB, MP		
129	Mr Karugu	Nyathona	Spinach, 2 mth	sm	BB, MP		
130	Mr Karugu	Nyathona	Spinach, 2 mth	sc, sm	BB, MP		
131	Mr Karugu	Nyathona	Spinach, 2 mth	sm	BB, MP,		
132	Mr Njunge Kuria	Nyathona	Spinach, 1yr	sm	BB, MP		
133	Mr Njunge Kuria	Nyathona	Spinach, 1yr	sm	BB, MP		
134	Mr Njunge Kuria	Nyathona	Spinach, 1yr	distortion	BB, MP		
135	Mr Njunge Kuria	Nyathona	Spinach, 1yr	sm	BB, MP		
136	Mr.Paul Maingi	Athi River	Kale	sm	BB, DBM	CaMV	TuMV
137	Mr.Paul Maingi	Athi River	Kale	sm		CaMV	TuMV?
138	Mr.Paul Maingi	Athi River	Kale	sm		CaMV	TuMV?
139	Mr.Paul Maingi	Athi River	Kale	sc	DBM, MP	CaMV	TuMV
140	Mr.Paul Maingi	Athi River	Kale	sc	DBM	-	TuMV
141	Mr.Paul Maingi	Athi River	Kale	yellowing, sc		CaMV	TuMV
142	Mr.Paul Maingi	Athi River	Kale	sc	Thrips	-	TuMV
143	Mr.Paul Maingi	Athi River	Kale	sc		-	TuMV
144	Mr. Samuel Mangeli	Athi River	Kale	sc		-	TuMV

Sample	Farm	Location	Host	Symptoms	Insect	CaMV	TuMV
145	Mr. Samuel Mangeli	Athi River	Kale	sm		-	TuMV
146	Mr. Samuel Mangeli	Athi River	Kale	sc		CaMV	TuMV
147	Mr. Samuel Mangeli	Athi River	Kale	sm		-	TuMV
148	Mr. Samuel Mangeli	Athi River	Kale	sm		CaMV	TuMV
149	Mr. Samuel Mangeli	Athi River	Kale	sc		-	TuMV
150	Mr. Samuel Mangeli	Athi River	Kale	sc		-	TuMV
151	Mr. Samuel Mangeli	Athi River	Kale	sc	BB	-	TuMV
152	Mr. Samuel Mangeli	Athi River	Spinach	sc		-	-
153	Ms. Jane Mutisya	Athi River	Gloria cabbage	black rot		-	TuMV
154	Ms. Jane Mutisya	Athi River	Gloria cabbage	yellowing, sm		-	TuMV
155	Ms. Jane Mutisya	Athi River	Gloria cabbage	sc		-	TuMV
156	Ms. Jane Mutisya	Athi River	Gloria cabbage	yellowing, sc		-	TuMV
157	Ms. Jane Mutisya	Athi River	Gloria cabbage	yellowing		-	TuMV
158	Ms. Jane Mutisya	Athi River	Gloria cabbage	yellowing		-	TuMV
159	Ms. Jane Mutisya	Athi River	Gloria cabbage	sc		CaMV	TuMV
160	Ms. Jane Mutisya	Athi River	Gloria cabbage	yellowing		-	TuMV
161	Ms. Jane Mutisya	Athi River	Gloria cabbage	yellowing, sc		-	TuMV
162	Daniel	Kirenga	Pructor (F1)	sc		-	TuMV
163	Daniel	Kirenga	Pructor (F1)	sc	DBM	-	TuMV
164	Daniel	Kirenga	Pructor (F1)	sc		-	TuMV
165	Daniel	Kirenga	Pructor (F1)	sc	DBM	-	TuMV
166	Daniel	Kirenga	Pructor (F1)	sc	DBM	-	-
167	Daniel	Kirenga	Pructor (F1)	sc		-	TuMV
168	Daniel	Kirenga	Pructor (F1)	sc		-	-
169	Daniel	Kirenga	Pructor (F1)	sc		-	-
170	Kula Akili	Kinale	Victoria F1	sc	DBM	-	TuMV
171	Kula Akili	Kinale	Victoria F1	distortion	DBM	-	-
172	Kula Akili	Kinale	Victoria F1	sc	DBM	-	-
173	Kula Akili	Kinale	Victoria F1	sc	DBM	-	-
174a	Kula Akili	Kinale	Victoria F1	sn			
174b	Kula Akili	Kinale	Victoria F1	sclerotinia			
175	Mr. Charles Nduhiu	Ngajina, Kinangop	Kale	sm	DBM, BB		
176	Jane Wanjiru	Ngajina, Kinangop	Kale	purpling, sc	BB		
177	Jane Wanjiru	Ngajina, Kinangop	cabbage	sc	DBM, BB		
178	Jane Wanjiru	Ngajina, Kinangop	cabbage	sc	DBM		

Sample	Farm	Location	Host	Symptoms	Insect	CaMV	TuMV
179	Jane Wanjiru	Ngajina, Kinangop	cabbage	sc	DBM, BB		
180	Jane Wanjiru	Ngajina, Kinangop	cabbage	none	DBM		
181	Jane Wanjiru	Ngajina, Kinangop	cabbage	none	DBM		
183	Jane Wanjiru	Ngajina, Kinangop	spinach	sm			
184	Mr Kariuki	Ngajina, Kinangop	cabbage	sc	BB	-	TuMV
185	Mr Kariuki	Ngajina, Kinangop	cabbage	sc			
186	Mr Kariuki	Ngajina, Kinangop	cabbage	sc, sm			
187	Mr Kariuki	Ngajina, Kinangop	cabbage	sc	DBM, BB		
188	Mr Kariuki	Ngajina, Kinangop	cabbage	purpling			
189	Mr Kariuki	Ngajina, Kinangop	cabbage	sc	DBM, BB	CaMV	-
190	Mr Kariuki	Ngajina, Kinangop	cabbage	sc	DBM, BB		
191	Farm 32	Gacheru Yang'a	Kale	distortion			
192	Farm 32	Gacheru Yang'a	Kale	sc			
193	Farm 32	Gacheru Yang'a	Kale	sc			
194	Farm 32	Gacheru Yang'a	Kale	purpling			
195	John N'Jao	Mukeu	Cabbage	sc	DBM		
196	John N'Jao	Mukeu	Cabbage	sc	DBM, BB		
197	John N'Jao	Mukeu	Cabbage	purpling, sc	DBM		
198	John N'Jao	Mukeu	Cabbage	sc			
199	Michael Mwanika	Cheese	Cabbage	sc	DBM		
200	Michael Mwanika	Cheese	Cabbage	sc	DBM, BB		
201	Michael Mwanika	Cheese	Cabbage	sc	DBM		
202	Michael Mwanika	Cheese	Cabbage	sc	DBM		
203	Michael Mwanika	Cheese	Cabbage	sn		-	TuMV
204	Joseph Kiilu	Kinale, Kirenga	Kale	sc	DBM		
205	Joseph Kiilu	Kinale, Kirenga	Kale	sc	DBM		
206	Joseph Kiilu	Kinale, Kirenga	Kale	sm	DBM		
207	Joseph Kiilu	Kinale, Kirenga	Kale	sc	DBM, BB		
208	Joseph Kiilu	Kinale, Kirenga	Kale	sc, sm	BB	-	TuMV
209	Henry Kanaya	Kinale, Kambaa	Kale	sc	DBM		
210	Henry Kanaya	Kinale, Kambaa	Kale	sc, sm	DBM, BB, MP		
211	Henry Kanaya	Kinale, Kambaa	Kale	sc, sm	DBM	-	TuMV
212	Henry Kanaya	Kinale, Kambaa	Kale	sc	DBM		
213	Henry Kanaya	Kinale, Kambaa	Kale	sc			
214	Henry Kanaya	Kinale, Kambaa	Kale	sc		CaMV	-

Sample	Farm	Location	Host	Symptoms	Insect	CaMV	TuMV
215	Henry Kanaya	Kinale, Kambaa	Kale	sm	DBM, BB		
216	Henry Kanaya	Kinale, Kambaa	Kale	sc	DBM, BB		
217	Henry Kanaya	Kinale, Kambaa	Kale	sm	DBM	-	TuMV
218	Henry Kanaya	Kinale, Kambaa	Kale	purpling, sc	DBM		
219	Joseph Mungai	Kinale, Kambaa	Kale	sc		CaMV	-
220	Joseph Mungai	Kinale, Kambaa	Kale	sc		-	TuMV
221	Joseph Mungai	Kinale, Kambaa	Kale	sc			
222	Joseph Mungai	Kinale, Kambaa	Kale	sc, sm	BB	-	TuMV
223	Joseph Mungai	Kinale, Kambaa	Kale	sn, sc		-	TuMV
224	Joseph Mungai	Kinale, Kambaa	Kale	sc	BB		
225	Joseph Mungai	Kinale, Kambaa	Kale	sc	BB		
226	Joseph Mungai	Kinale, Kambaa	Kale	distortion			
227	Sarah Nyambura	Kinale, Was Huho	Kale	sc	DBM, BB		
228	Sarah Nyambura	Kinale, Was Huho	Kale	sc	DBM		
229	Sarah Nyambura	Kinale, Was Huho	Kale	sc, sm	DBM, BB	-	TuMV
230	Sarah Nyambura	Kinale, Was Huho	Kale	sc, sm	DBM, BB	-	TuMV
231	Sarah Nyambura	Kinale, Was Huho	Kale	sc, sm	DBM, BB		
232	Ann Wambui	Kinale, Was Huho	Kale	purpling, sc	DBM, BB		
233	Ann Wambui	Kinale, Was Huho	Kale	sc	BB		
234	Ann Wambui	Kinale, Was Huho	Kale	sc, sm	DBM		
235	Ann Wambui	Kinale, Was Huho	Kale	purpling, sc	DBM		
236	Ann Wambui	Kinale, Was Huho	Kale	sc	DBM, BB		
237	Ann Wambui	Kinale, Was Huho	Kale	sc	DBM, BB		
238	Paul Maingi	Athi River	Kale	sm		-	TuMV
239	Paul Maingi	Athi River	Kale	sc	BB	CaMV	-
240	Paul Maingi	Athi River	Kale	sm	DBM	-	TuMV
241	Paul Maingi	Athi River	Kale	sc	LP, thrips	-	TuMV
242	Paul Maingi	Athi River	Kale	sc			
243	Petero	Athi River	Kale	distortion	DBM, MP	-	TuMV
244	Petero	Athi River	Kale	sm	DBM, BB	CaMV	-
245	Petero	Athi River	Kale	sc	DBM, BB	-	TuMV
246	Petero	Athi River	Kale	sc		-	TuMV
247	Petero	Athi River	Kale	sc		-	TuMV
248	Petero	Athi River	Kale	sc	BB		
249	Petero	Athi River	Kale	sc	LP	-	TuMV

Sample	Farm	Location	Host	Symptoms	Insect	CaMV	TuMV
250	Petero	Athi River	Kale	sc	BB	-	TuMV
251	Petero	Athi River	Kale	sc	BB	-	TuMV
252	Petero	Athi River	Kale	sc	MP	CaMV	TuMV
253	Jane Mutisya	Athi River	Cabbage	sc	DBM		
254	Jane Mutisya	Athi Riverh	Cabbage	sc	DBM	-	TuMV
255	Jane Mutisya	Athi River	Kale	sc	DBM, LP		
256	Jane Mutisya	Athi River	Kale	sc	DBM	-	TuMV
257	Jane Mutisya	Athi River	Kale	sc	DBM		
258	Edward Njer	Athi River	Kale	sc	DBM		
259	Edward Njer	Athi River	Kale	sc	DBM, LP		
260	Edward Njer	Athi River	Kale	sc	DBM		
261	Edward Njer	Athi River	Cabbage	sc	DBM		
262	Edward Njer	Athi River	Cabbage	sc	DBM		
263	Edward Njer	Athi River	Cabbage	sc	BB		

Appendix 4

MANAGEMENT OF VEGETABLE VIRUS DISEASES IN KENYA: FARMER PERCEPTIONS AND EVALUATION OF CONTROL STRATEGIES

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ACRONYMS

CABI-ARC	CAB International, Africa Regional Center
FGDs	Focus Group Discussions
KARI	Kenya Agricultural Research Institute
PRA	Participatory Rural Appraisal
DBM	Diamond Back Moth
DFID	Department for International Development of the United Kingdom

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1. INTRODUCTION

Market gardening and horticultural enterprises represent a significant source of income for many small- to medium-scale farmers in Kenya. Farmers, especially around towns, rely on vegetables for employment, income generation and as a source of food. Additionally, the rapidly increasing urban population presents a major challenge to the agricultural production sector to provide an adequate food supply to the growing urban centres. The production system in these peri-urban areas is characterised by high value crops such as vegetables, intensive land use and high use of pesticides. This intensive vegetable production, whilst generating high incomes, also has disease and pest problems which can build up to very high levels threatening sustainability of the farms. The excessive use of chemical pesticides to control pests and diseases has led to increasing concern about residues in the produce, operator exposure, development of resistance and environmental damage, and damage to beneficial natural enemies.

The project “Management of virus diseases of important vegetable crops in Kenya” aims to develop improved methods for the control of virus diseases in brassica crops in the peri-urban vegetable systems through the identification of virus resistant germplasm, use of cultural control methods to reduce virus incidence and spread, and improved vector control. On-station trials of various cultural control methods have been undertaken and these have proved promising for the control of virus diseases. The next step is to extend these trials on farm in order for the methods to be tested under field conditions, and for them to be evaluated by farmers who are the end users.

The objectives of the socio-economic component of the project were to;

- Evaluate farmer knowledge and perceptions of viral diseases and their vectors, any control methods being used, production constraints and the importance of viral diseases relative to other constraints
- Determine the potential for farmer selection of seeds of resistant/tolerant components of kale land races.
- Evaluate how farmers’ perceptions of viruses have changed over the period of study as a result of disease management strategies advocated by the project.

Based on the objectives of the project, it was apparent that there was need for participatory research with farmers. One goal of encouraging farmer participation in this project was to ensure more wider and quicker adoption of the disease control technologies and to empower and strengthen the capacity of farmers to make decisions on disease control (CIAT, 1997). There were several levels of participation;

- Participatory Rural Appraisals with groups of farmers to identify their production constraints and perceptions of some of these constraints and for farmers to contribute to the project objectives,
- A learning and empowerment process where farmers are empowered through knowledge acquisition and methodologies for evaluating technologies,
- Farmers validating technologies before making the decisions on whether to take the technologies or not and using farmer's fields as the experimental fields

This project therefore took both a consultative and action oriented participation by the farmers and the first step in this process was to find the interface between the project team and the farmers. This project took an innovative step by using Participatory Rural Appraisal (PRA) to identify existing farmer practices, and incorporating the outcome into the formal project objectives.

This report is divided into 6 parts;

1. An introduction
2. PRA to gauge initial farmer perceptions of viral diseases and to find an entry point for farmer participation
3. Farmer evaluation of technologies through participatory budgeting during on farm trials at two sites
4. Change of farmer perceptions on viral diseases as a result of the on farm trial
5. On farm farmer seed selection and its evaluation by farmers
6. Conclusions and recommendations

Sections 2 to 5 describe the objectives, activities and results for each part of the study.

2. PRA TO ASSESS FARMER PROBLEMS, PERCEPTIONS AND PRACTICES IN RELATION TO VIRUS DISEASES AND THEIR INSECT VECTORS

2.1 Introduction

A PRA was carried out at two selected sites in Athi River and Ruiru where farmers grow brassicas for both commercial and domestic use. A PRA was used as a quick and efficient way of determining farmer perceptions, local knowledge and constraints in vegetable production and as a starting point for involving the farmers in testing disease control strategies under farm conditions.

2.1 Objectives

The aim of the PRA was to;

- Evaluate farmer perceptions of virus symptoms and relative importance compared to other production constraints
- Obtain local knowledge of virus diseases and any current control measures
- Identify constraints on improved control measures such as costs and practicability
- Evaluate perceptions of resistance/susceptibility of land races of kale and cabbage to virus symptoms
- Compare social and cultural variations in farmer perceptions and practices.
- Gauge farmers' willingness to participate in on-farm trials.

2.3 Methods

Two sites were selected for on-farm trials on low input methods for reducing vector transmission of viruses in seedbeds. These methods included the use of straw, mulch and re-usable fleece. The two sites selected were Ruiru and Athi River both situated on the outskirts of Nairobi. During a previous survey, these two areas were identified as having high levels of diseases on cabbage, kale and spinach (Oruko and Ndungu, 2001). Focus group discussions (FGDs) with farmers were held at these two sites with a checklist used to guide the discussions. The checklist is shown in Appendix 1. A wealth ranking exercise was included in the focus group discussion to enable the classification of farmers into different

social categories for the evaluation of the control methods. A team of 2 socio-economists, a plant pathologist and a field technician facilitated the discussions.

2.4 Results

2.4.1 General information on farmers involved in the FGDs

In Ruiru farmers were already members of a group, all farming along the Ruiru River and growing vegetables. In Athi River there was no formal organization of farmers, and individual farmers were brought together to participate in the PRA and in subsequent on-farm trials. All farmers were growing vegetables under irrigation. Farmers at both sites were growing vegetables both for on-farm consumption and for sale in neighbouring markets.

2.4.2 Farmer wealth ranking

This activity involved classifying farmers based on various social and economic characteristics as a first step in the evaluation of differences in perceptions of viral diseases and their control between the different categories. Farmers at both sites initially identified indicators of wealth or what they thought were the characteristics associated with wealth. Social categories found important for this evaluation included asset ownership, financial ability, type of household and education level among others.

Farmers in Athi River gave the indicators of wealth as; number of cattle, crop varieties and number of crops grown, size of land, type of house, access to irrigation water, ownership of irrigation equipment, access to hired labour, operating capital available and farmer experience. In Ruiru wealth was associated with; type of house, number of cars, size of land and number of plots, crop mix, access to irrigation and farming equipment, number of cattle, children's education, standard of living, access to hired labour, ownership of a bicycle and the operating capital available. Farmers then identified three categories of farmers to be rich, medium or poor and defined each of the indicators according to the categories. The categories and the definitions of the indicators for each site are given in Appendix 2.

These indicators to categorise farmers during the evaluation of the tested and promoted technologies.

2.4.3 General problems and constraints in vegetable production and marketing

Farmers identified different vegetable production constraints and ranked them according to their importance.

Farmers in both Ruiru and Athi River ranked diseases and pests as the most important constraint in vegetable production and marketing whilst lack of finance and quality seeds were the second most important constraints in the two districts, respectively.

Table 1. Vegetable production constraints

Athi River		Ruiru	
Rank	Constraint	Rank	Constraint
1	Insect pests and diseases	1	Insect pests and diseases
2	Lack of quality seeds	2	Lack of finance
3	Lack of credit/finances	3	Market flooding
4	Lack of information on diseases and methods of control	4	Transport to markets
		5	Soil nutrient deficiencies
5	Market flooding causing low prices	6	Expensive inputs especially pesticides
6	Water pollution		
7	Lack of experience in vegetable farming	7	Low quality of seed
		8	Lack of technical information on vegetable growing
8	Weather		
9	Wildlife menace		
	Unavailability of water		

Of significance is the fact that as well as ranking pests and diseases as the most important constraint to vegetable production, farmers in Athi River also ranked lack of information on diseases and their control as the fourth most important constraint. Expensive inputs, especially pesticides, were mentioned as a production constraint in Ruiru. This is of relevance to the vegetable virology project, which is looking at non-chemical control methods for viral diseases.

2.4.4 Farmer ranking of common kale and cabbage varieties

Farmers ranked the varieties of kale and cabbage grown in Ruiru and Athi River in order of preference. Thousand-headed variety of kale was described by farmers in both Athi River and Ruiru as being more susceptible to most of the diseases, including viral diseases, than the collard variety. Farmers had not observed any differences in susceptibility to diseases and pests among the cabbage varieties**.**

Table 2. Landraces and varieties preferred by farmers in terms of least susceptibility to diseases

Athi River		Ruiru	
Kales	Cabbage	Kales	Cabbage
Collard Thousand headed	Gloria Sugarloaf Drumhead Copenhagen Amukos	Collards Thousand headed Kinale	Copenhagen Gloria Amigo Amukos Fortuna

2.4.5 Farmers' perceptions of virus diseases

In general terms, farmers in Ruiru were more knowledgeable on the symptoms and causes of insect pests and diseases than those in Athi River. One of the reasons for this could be because the farmers in Ruiru were already members of a group and some of the group members have been going for farmer training on various crops and crop management practices. Few of the farmers in Athi River had a clear perception of the relationship between disease carrying vectors and the disease symptoms that they cause.

Athi River

Farmers were given a leaf showing various symptoms of viral diseases, and were asked to identify the symptoms and to suggest possible causes of these symptoms. The group identified the symptoms as yellowing of leaves and rough leaf surface. They attributed these to too much water, too much use of manure and fertilizer or too much watering followed by heavy rains. Some of the farmers also thought that the problem starts from the stem based on their observation of black and white strips on the stem of the affected plants. The control

for these symptoms according to the farmers is removal of affected leaves. Indeed they have observed that once the infected leaves are removed, the younger leaves remain healthy. They attribute this to the fact that the plant is able let water out through the injury that is left when the infected leaves are removed, thus releasing excess water from the plant.

When probed on the possible relationship between the yellowing of leaves and aphids, only one farmer related the two. Probed on what this relationship between aphids and yellowing of leaves could be, they attributed the yellowing of leaves to the aphids sucking water from the leaves, leaving the leaves yellow and finally causing drying up of the leaves. Other farmers felt that due to the high nutrient levels associated with the yellowing, the plant would be too strong to be affected by aphids. Yellowing of leaves was also associated to blight and potassium deficiency by some farmers. The blighted leaves were believed to turn yellow when rained on.

Some of the farmers associated aphids with black rot believing that when the aphids settle on the cabbage before the head forms, the aphids are engulfed and this causes them to die and rot causing the whole cabbage head to rot.

Table 4. Summary of symptoms and their causes in Athi River

Symptoms	**Causes**	**Control**
Yellowing of leaves Rough leaf surface	Excess use of manure Too much watering Blight Potassium deficiency	Remove yellow leaves Regulate watering Spraying pesticides

Ruiru

When farmers in Ruiru were shown leaves infected with viral disease, they identified the symptoms as yellowing and curling of leaves and blackening or colouration of the leaf veins. The farmers associated yellowing of leaves to aphids, cold weather and mites. Similar to the lone farmer in Athi River who associated aphids to yellowing of leaves, farmers in Ruiru hypothesized that the aphids suck sap from the plant reducing the amount of water available

for the leaves to be healthy. They attributed the virus symptoms to DBM, aphids which suck sap from the leaves, low quality seeds, insufficient fertilizer (nutrient deficiency), lack of potassium, weeds which cover the kale and prevent it from getting enough sunlight and cold. The whitish powder on the leaves was linked to powdery mildew, which some farmers identified by name.

Table 4. Summary of symptoms and their causes in Ruiru

Symptoms	**Causes**	**Control**
Yellowing of leaves Curling of leaves Blackening of veins	Aphids Cold weather Mites DBM Nutrient deficiency Weeds	Sufficient fertilizer application Spraying dimethoate

The farmers in Ruiru seemed to be more aware of other diseases, sometimes mentioning them by name, than they are aware of virus diseases. There is, however, some degree of recognition that aphids, the vectors for viral disease are linked to the yellowing of leaves, one of the symptoms of viral diseases. The fact that they think aphids cause the yellowing by sucking also indicates that they associate the infection to the feeding activities of aphids. This has important implications for the on farm control trials since the major rationale for these trials is to control aphids as a way of controlling viral diseases.

2.4.6 Evaluation of the effect of various symptoms on marketability, pricing and palatability of kale and cabbage

Farmers were asked to evaluate different symptoms in terms of what effects they had on marketability, price and palatability. On a scale of 0-5, farmers gave the following evaluation.

Table 5. Disease and pest evaluation in Ruiru

Disease/pest symptoms	**Marketability**	**Price**	**Palatability**	**Total**	**Rank**
White fly	1	1	1	3	B

Yellowing of leaves	3	2	3	8	A
Rot	0	0	1	1	C
Curling of leaves	3	2	3	8	A
Mites	0	0	0	0	D

0-total effect 5-minimum effect

This evaluation shows that there are other pests and diseases other than viral diseases that farmers consider more critical to the marketability and prices of their cabbages and kales. These cause total loss of the affected parts as they cannot be marketed or they cannot be consumed. Yellowing and curling of leaves, which are symptoms of virus diseases, were evaluated as having moderate effects on the marketability, cost and palatability, although farmers had earlier indicated that affected leaves are normally just thrown away. Farmers had differing opinions of the disease so generalization is difficult. It may be more of a reflection of the market conditions in the two areas.

2.4.7 Control methods used by farmers

Most of the control methods used by farmers are based on the application of pesticides. However, in identifying the production constraints, farmers in Athi River ranked lack of information on diseases and appropriate controls as the number 4 problem whilst those in Ruiru ranked expensive pesticides as their number 6 problem. There is need to focus more on cultural control methods that are more environmentally friendly and affordable to farmers.

2.5 Discussion

Farmer knowledge of virus disease was very low with majority of the farmers associating virus symptoms low soil fertility, over watering, over fertilizing and potassium deficiency. In Athi River, there was a very weak link by farmers between aphids, which are the vectors for viral diseases, and symptoms of viral diseases. In Ruiru, farmers were more knowledgeable of the link between aphids and some of the symptoms. The most common methods used by farmers for the control of virus diseases were the removal of affected leaves and spraying dimethoate. Constraints that farmers faced were insect pest and diseases, lack of quality seeds, lack of information on pests and diseases among others.

Collard kales were though by farmers to be less susceptible to diseases than thousand

headed. Farmers in Athi river ranked Gloria as the least susceptible, followed by sugar loaf and drum head while farmers in Ruiru preferred Copenhagen as they found it to be less susceptible to diseases than the others.

Farmers indicated that they require insect pest and disease control methods that are cheap and simple to manage. In order to compare the control methods suggested by the virus project and the current farmer practice, it was decided that a farmer control plot would be included in the on-farm trials. There was a discussion on the common practice for viral disease control by the farmers and this was included as a treatment. Apart from evaluating yield, aphid and virus incidence, a participatory budgeting exercise was planned in order to evaluate the cost and labour implications of the different control methods and to compare them with the farmer practice.

3. EVALUATION OF ON FARM TRIALS BY FARMERS USING PARTICIPATORY BUDGETING TECHNIQUES.

3.1 Introduction

Participatory budgeting[1] is a technique that draws on farm management and participatory rural appraisal principles. It helps farmers working with researchers and extensionists to plan and analyze activities and their related resource use and production benefits. For the purpose of this trial, the participatory budgets enabled farmers and the researchers to evaluate the financial feasibility and implications of different disease control strategies and the suitability of these strategies. The advantage of these budgets is that they are simple to follow, use local materials and also take into account non-cash resources such as labour. Two farmer groups were involved in the participatory budgeting process, Athi River and Ruiru. The Ruiru group did not go through the whole experiment due to internal group and leadership problems, which affected the activities of the experiment. The group was replaced with a group of farmers focused on organic production (Kariguini) who had earlier been involved in a project on the control of root knot nematode.

The purpose of these on farm trials, in addition to validating earlier on station experiments on the effectiveness of various virus disease control strategies, was to provide the farmers with a basis by which they could evaluate the different control options in terms of the cost implications as well as other criteria that determine farmer decision making with respect to pest controThe rationale for this was that farmers would be able to compare the control methods not only in terms of their effectiveness in controlling the diseases but also in terms of the cost implications. It was expected that farmers would appreciate cost savings obtained when simple cultural methods that are effective are used for disease control. It was also expected that once the farmers had their own evaluation of the treatments, it would speed up adoption of the control methods.

3.2 Objectives of the participatory budgeting

The objectives of the participatory partial budgeting exercise were

[1] The methods for participatory budgets were developed by Peter Doward and Mark Galpin of the Department of Agriculture and Derek Shepherd, Head of AERDD in a DFID funded project.

- To evaluate the feasibility, implications and suitability of different viral disease management strategies
- To stimulate farmer interest and participation in the off farm trials by using the budgets as the farmer led research component in the on farm trials
- To stimulate discussion among farmers on viral diseases and the different control strategies.

3.3 The process

3.3.1 Viral disease control strategies and setting up the on farm trial

There were two management strategies to be evaluated, use of fleece and use of mulch. In addition there was a control and arising from the initial PRA described in part 2, it was decided to include a farmer practice treatment. This was the use of dimethoate for the control of aphids. Therefore at nursery level there were four treatments; mulch, fleece, dimethoate and control. During transplanting each of the four nursery treatments was divided into two in the field, mulch and no mulch treatment while the dimethoate treatment was divided into a mulch and dimethoate treatment. This gave rise to eight treatment combinations.

Table 6. Treatment combinations

No	Nursery treatment	Field treatment
1	Mulch	Mulch
2	Mulch	No mulch
3	Fleece	Mulch
4	Fleece	No mulch
5	Dimethoate	Dimethoate
6	Dimethoate	No mulch
7	Control	Mulch
9	Control	No mulch

3.3.2 Farmer understanding of the budgeting process

At the start of the budgeting process, the objective of the trial was discussed with farmers. The participatory budgets were introduced as a way for the farmers to evaluate the disease management strategies in terms of what is feasible for them. The difference between the partial budgets and full budgets was explained; partial budgets look at the differences

between the strategies rather than the overall profitability of each of the strategies. All the farmers in Athi River were literate and so the budgeting process was done on flipcharts with a high level of participation by farmers in recording activities and inputs used in the experiment. In Kariguini most of the farmers were literate but for the benefit of those who were not, dramatization or use of physical objects to demonstrate the various aspects of the experiment were used.

3.3.3 Implementation of the participatory partial budgeting process

3.3.3.1 Inputs data collection

An inputs data sheet was developed together with farmers and agreement reached on how to use the sheet to record activities, dates when the activities took place, what inputs were used, the quantities and where possible, the prices. Farmers were also trained on basic record keeping as part of their own farm management.

Figure 1. Farmers learning the concepts of record keeping and inputs entry for the participatory partial budgets.

The input data collection was done at the site after each day's activities. For each day a record was made of the date, activity carried out, all input items including equipment, labour and consumables, details of the amount of each input item and number of plots covered and the cost of inputs. Separate input sheets were made for each treatment and a common sheet input sheet was kept for all the activities that were done on all treatments. After the first recording of inputs by the socio-economist, subsequent activities and inputs were done by the farmers themselves under the guidance of the socio-economist or other team member.

Table 7. An example of an input sheet from Athi River

Treatment: Mulch

Date	**Activity**	**Input**	**Quantity, unit and number of plots**	**Cost**
2/1/2002	Putting mulch	Mulch Labour for putting mulch	1 bale for 4 plots 40 minutes/4 plots	180Ksh/bale
3/2/2002	Removing mulch	Labour for removing mulch	30 minutes/4 plots	

During each activity a farmer would be selected by the others to enter the details for that activity for that day.

3.3.3.2 Constructing the partial budget-phase one

Phase one of the participatory budget was carried out before transplanting (a month after initiating the trial). This started with a review of the experiment to ensure farmers still understood the purpose of the experiment and the different treatments.

Inputs were reviewed to make sure all had been included in the input record sheet. At this stage, all the inputs were listed in order to determine those that would go into the partial budget and those that would not. All inputs that were common to all treatments were

removed from the partial budget. Inputs that would not be used in a real farm situation were also crossed out of the list. For example, in the dimethoate trial, four farmers would hold a sheet around the plot to ensure that the dimethoate did not blow over to other plots. In a real farm situation, a farmer would have only one treatment and holding the polythene sheet would not be necessary. The labour of these four farmers was therefore not included in the partial budget. The input lists were then transferred to the budget sheet and the quantities added up.

Table 8. Layout for the input budget sheet

Variable	Control	Mulch	Fleece	Dimethoate

The quantities for each item in treatment were then added up one input at a time for all treatments to make a quantities table as table 8.

The inputs were then priced as follows.

- Farm labour: A value for labour of ksh 100 for a 5 hour day was agreed on by farmers as appropriate. This used farm hired labour as an equivalent to family labour. Farmers gave a value of Ksh 80 for female labour and Ksh 130 for male labour. After discussions, they agreed to use Ksh 100 irrespective of whether it was male or female labour.
- Dimethoate and polythene bags: These were available locally and the market price for them was used.
- Fleece: The price was given based on the cost price of the fleece in the UK. However, it was understood by farmers that slight adjustments would be made to the costs if the fleece were available locally.

The costs were then added up for each treatment.

3.3.3.3 Constructing the partial budget-phase two

a) Input quantification and costing

This was done after maturity of the crop in the transplanted field. The inputs were quantified and priced as in the first phase.

b) Output quantification and costing

As the harvesting was done, farmers evaluated the price of each cabbage based on how much they would sell that cabbage for in the local market. Unmarketable cabbages were excluded from the analysis. In addition, the weight of each cabbage was taken for later statistical analysis.

c) Calculating the extra costs

The costs for the nursery and the field trial per plot were then combined for each treatment as shown in Table 9.

Table 9. Calculations of extra costs of treatments compared to the control (Ksh)

	Control to no mulch	Control to mulch	Dimethoate to mulch	Dimethoate to Dimethoate	Fleece to mulch	Fleece to no mulch	Mulch to Mulch	Mulch to no mulch
Nursery	0	0	18	18	33.25	33.25	33.75	33.75
Field	0	179.8	179.8	27	179.8	0	179.8	0
Total	0	179.8	197.8	45	213.05	33.25	213.55	33.75

(Conversion rate at Ksh 110 to UK£**)**

This also formed the extra costs table comparing all other treatments to the control. The methodologies for participatory partial budgets require a comparison of each treatment with the others. This was however found to be confusing to the farmers due to the many treatments. At this stage therefore, the treatments were only compared to the control. The whole concept of the partial budget, extra costs, extra output and the benefits was illustrated using visual aids. This was done by one of the farmers using bottles. One treatment and a control were assumed. Farmers were then asked to put two piles for inputs, one for the control and one for the treatment. They rationalized that the treatment would have higher inputs than the control. The bottles from the control pile were then subtracted from the bottles on the treatment pile to get the extra inputs incurred from using the treatment instead of the control. They were then asked to put another two piles for outputs and repeat the process. Again, they assumed that since they had put more inputs in the treatment, they

would get more output form it than from the control. To get the extra output, the bottles on the control pile were subtracted from the treatment pile. Now to answer the question of whether it was worth taking the treatment as opposed to having the control, the farmers counted the bottles left on the inputs pile and compared with those left on the output piles. The output pile had more bottles, so the conclusion was that the extra output from using the treatment would pay for the extra input and farmers would still be left with a profit. Therefore, it would be worth using the treatment.

d) Comparing extra costs with output

Combining the extra costs data and the output data allowed for calculation of the extra output as shown in Table 10.

Table 10. Comparing extra costs with outputs

	Control to no mulch	Control to mulch	Dimethoate to mulch	Dimethoate to Dimethoate	Fleece to mulch	Fleece to no mulch	Mulch to Mulch	Mulch to no mulch
Costs	0	179.8	197.8	45	213.05	33.25	213.55	33.75
Output	61.90	118.25	305.25	434.75	258.75	136.5	144.0	43
Extra output	0	56.35	243.35	372.85	196.85	74.6	82.1	-18.9

The mulch to no mulch treatment had the lowest output while the dimethoate to dimethoate had the highest. The fleece to mulch also performed well in terms of output ranking third after the dimethoate to dimethoate and the dimethoate to mulch.

The questions posed to the farmers to understand these concepts were;

If you did not follow any of the management strategies, the output would have been ksh 61.90 (which is the output of the control to no mulch strategy), how much more would you have got by adopting any one of the strategies compared to the control?

Due to flooding of the experiment with the Kariguini group, there was no yield data and from this point onwards, the group used data from the Athi River group both for the inputs and the outputs for ease of comparison.

e) Constructing the benefits table

We then constructed the extra benefits table, which subtracted the extra costs of adopting a strategy from the extra output obtained from adopting that strategy.

The question therefore was;

Does the extra output for each of the treatments cover the extra costs that you put in to obtain this output?

Table 11. Calculating the benefits

	Control to mulch	Dimethoate to mulch	Dimethoate to Dimethoate	Fleece to mulch	Fleece to no mulch	Mulch to Mulch	Mulch to no mulch
Extra output	56.35	243.40	372.85	196.85	74.6	82.1	-18.9
Extra Costs	179.8	197.8	45	213.05	33.25	213.55	33.75
Benefits	**-123.4**	**45.6**	**327.85**	**-16.2**	**41.35**	**-131.45**	**-52.65**
Rank	**6**	**2**	**1**	**4**	**3**	**7**	**5**

The extra output from the dimethoate to mulch, dimethoate to dimethoate and fleece to no mulch all paid for the extra inputs that had been incurred. The output from all the other treatments could not pay for the extra inputs used in these treatments.

The initial reaction by farmers in Athi River was that spraying seemed to be the most profitable of the treatments. They ranked the spraying treatment as the best (spray in nursery and spray in field) followed by the spray/mulch treatment (spray in the nursery and mulch in the field). The reaction from Kariguini which is an organic group was however different. They preferred the mulch and fleece treatments, as these were more environment friendly than the dimethoate treatment. Since the output from these treatments was not very low, they concluded that if they reduced the cost of inputs by for example collecting mulch rather than buying it, then the benefits of using mulch would be positive.

3.4 Statistical analysis of the data

The data was statistically analysed in order to take account of such issues as missing values and to standardize the results across the treatments. Statistical analysis of the gross plot prices, assuming 42 plants, was carried out using Analysis of Variance in Genstat (Genstat 4.2, 2000). Inter-block variation was taken into account and a p-value for

differences between the treatments was calculated. The standard error of the difference between any two treatments was used to make specific treatment comparisons. The partial budgets from this analysed data, both per plot and per ha are given below.

Table 12. Statistical partial budget (on a per plot basis)

	Control to mulch	Dimethoate to mulch	Dimethoate to Dimethoate	Fleece to mulch	Fleece to no mulch	Mulch to Mulch	Mulch to no mulch
Inputs	179.8	197.8	45.0	213.1	33.3	213.6	33.8
Output	130.0	312.0	399.0	282.0	136.0	156.0	47
Extra output	63.0	245.0	332.0	215	69.0	89.0	-20
Extra Costs	179.8	197.8	45.0	213.05	33.3	213.6	33.8
Benefits	**-116.8**	**47.2**	**287.0**	**2**	**35.8**	**-124.6**	**-53.8**
Rank	**6**	**2**	**1**	**4**	**3**	**7**	**5**

The budget was then converted into a per hectare basis so that it could be more logical to farmers. This was done using the following calculations.

1 plot had 42 plants

Spacing used was 60cm by 60cm Area of one plot was 15.12 sq metres

One nursery measured 1m by 2m

To plant 1 ha of cabbage, we would require 300g of seed

To get enough seedlings for 1 ha of cabbage requires a nursery of 18 sq metres

Therefore, the experiment would have required 9 nursery beds to transplant seedlings into I ha.

The output and inputs per plot were calculated using the formula

$$\frac{\text{inputs/outputs} * 10\,000}{\text{Area of plot (sq m)}}$$

Nursery expenses were multiplied by a factor of 9.

Table 13. Statistical partial budget (on a per ha basis)

	Control to mulch	Dimethoate to mulch	Dimethoate to Dimethoate	Fleece to mulch	Fleece to no mulch	Mulch to Mulch	Mulch to no mulch
Inputs	118 915	119 077	18 019	119 213	298.8	119,219	304.2
Output	85 978	206 349	263 888	186 507	89 947	103 174	31 084
Extra output	41 666	162 037	219 576	142 195	45 634	58 862	-13 227
Benefits (Ksh)	**-77 248**	**42 960**	**201 588**	**22 982**	**45 336**	**-60 357**	**-13 532**
Benefits (UK£)	**-702.3**	**390.5**	**1 832.6**	**208.9**	**412.1**	**-548.7**	**-123.0**
	7	**3**	**1**	**4**	**2**	**6**	**5**

Comparing these statistical budgets with the farmer budgets did not give a major difference. On a per plot basis, the fleece to mulch treatment, which had negative benefits in the farmer budget, now had positive benefits in the statistical budget. All other treatments with negative budgets in the farmer budget remained with negative benefits even with the statistical budget.

On a per ha basis, the order of ranking according to benefits changed. Dimethoate to dimethoate still had the highest benefits followed by the fleece to no mulch. The per plot analysis had the treatment with the second largest benefit as the dimethoate to mulch. In the per ha statistical budget, this treatment was ranked third. Four treatments (dimethoate to dimethoate, fleece to no mulch, dimethoate to mulch and fleece to mulch) had positive benefits in the per ha statistical budget while the other three (mulch to no mulch, mulch to mulch and control to mulch) had negative benefits.

This budget was then discussed with the two groups of farmers and was used for the final evaluation of the treatments.

3.5 Farmer discussions and evaluation of the various viral disease control strategies

The evaluation was done in form of a moderated focus group discussion with farmers. The first step in the evaluation was for farmers to remind themselves of the purpose of the experiment and the different treatments. Due to the complexity of using all 8 treatments for the evaluation, the farmers opted to evaluate the treatments broadly as mulch, fleece, dimethoate and control. The next step was then to identify what criteria other than financial benefits farmers thought were important for the evaluation. This was based on what they would consider if they were to make a decision on whether to adopt a certain disease

control strategy or not. Five criteria were selected; labour requirement, benefits, availability of materials, ability to control the disease and use of other inputs. The farmers then ranked each of the four treatments with the best getting a rank of 1 and the worst a rank of 4. The farmers were then asked to give a final score for each of the treatments. This was done by giving a total score of 100 for all the treatments and farmers allocating this 100 amongst the four treatments.

The final step of the evaluation was then to critically look at the 4 treatments and discuss what else they thought was good or bad about the particular treatment and would make them adopt or not adopt it.

3.5.1 Evaluation of results in Athi River

3.5.1.1 Ranking of treatments

Table 14. Farmers ranking of treatments in Athi River

Criteria/ treatment	Labour	Benefits	Availability	Disease control	Use of other inputs
Mulch	3	3	3	3	2
Fleece	2	2	4	2	3
Dimethoate	4	1	2	1	4
Control	1	4	1	4	1

The control treatment was ranked the best in terms of labour requirement with dimethoate being the most labour intensive. The mulch was ranked third. In terms of the benefits, dimethoate was ranked top while fleece was second and mulch third. In the use of other inputs, mulch was ranked second while dimethoate was ranked last. Dimethoate got a rank of 4 due to other requirements such as gloves, masks, spray pumps and other protective gear that is required for spraying.

Farmers were then asked to give a general score for each of the treatments from a score of 100. Dimethoate was given a score of 50, which was the highest score. This was followed by fleece, which had a score of 25, mulch with a score of 15 and last was the control with a score of 10.

3.5.1.2 Merits and demerits of disease control strategies

This involved farmers thinking beyond the disease control aspects of the treatments and discussing what would encourage or discourage them from adopting these treatments. The good points and the bad points of each of these treatments are summarized below.

Table 15. Merits and demerits of treatments in Athi River

Treatment	Merits	Demerits
Mulch	• Ability to retain water and moisture • Controls pests (aphids) and therefore viral diseases • Controls weeds • Prevents contact of plant with the ground	• Expensive • Can encourage other pests such as crickets and cutworms • May retain more moisture than necessary during heavy rains and after watering
Fleece	• Seedlings were of better quality than other treatments • Little labour required • Kept aphids out and hence controlled the disease • Yield was high • Retains moisture	• Expensive • Seedlings etiolated • Not easily available • Had weed problems
Spraying	• Controlled most pests and hence diseases • Yield was high • Good quality heads • Affordable	• Offensive smell • Labour intensive • Expensive to apply (need pump, masks, gloves etc) • Could be toxic • Pests develop resistance • Farmer may buy when it has expired • Takes long to degrade

Despite the many demerits of the dimethoate, it has been the most commonly used by the farmers in the control of aphids. However, those farmers who had access to mulch were willing to try it and see its performance under non-experimental conditions. The project team also provided the group with a piece of the fleece used during the experiment for further evaluation during the final PRA.

3.5.2 Evaluation of results in Kariguini

3.5.2.1 Ranking of treatments

Table 16. Ranking of treatments in Kariguini

Criteria/treatment	Labour	Benefits	Availability	Disease control	Use of other inputs
Mulch	2	1	1	1	1
Fleece	1	2	4	2	2
Spraying	4	4	3	3	3
Control	3	3	2	4	4

1=best 4=worst

Fleece was ranked highest in terms of labour requirements and second in terms of the benefits, disease control and use of other inputs. It was however ranked lowest in terms of availability since it is not available locally. The dimethoate was ranked very low in all criteria groups (lowest in terms of labour, benefits and third in terms of availability, disease control and use of other inputs). The farmers argued that the financial benefits from the use of dimethoate would be overshadowed by the environmental and health hazards as a result of the use of the dimethoate. In terms of disease control, they argued that the dimethoate is specific to only some pests and to control all the disease and pests that are a problem in kales and cabbages, they would need to purchase other types of chemicals.

Mulch came out very favourably with this group of farmers, because it would exclude the use of chemicals and because it is available locally. When probed on the high cost of the mulch as per the budgets, farmers indicated that they would not need to purchase mulch, as this was readily available. The only cost would be for the labour required to look for, cut and carry the mulch to their plots. The farmers also favoured fleece despite its unavailability, though they expressed a need for a local alternative to the fleece.

Farmers were then asked to give a general score to the treatments from a total score of 100. Mulch was ranked highest with a score of 40 followed by fleece with a score of 30. Dimethoate and control came third and fourth with scores of 20 and 10 respectively.

3.5.2.2 Merits and demerits of disease control strategies

The farmers agreed that the merits of both the mulch and the fleece outweighed their

demerits and they would like to try these two treatment options not only for the disease and pest control but also to reap the other benefits of the treatments. The major handicap was however availability of fleece. The project team agreed to provide the farmers with the fleece used for the experiment, and one of the assessments during the final see how many farmers had used either the fleece or the mulch and what the performance was compared to their normal practice.

Table 17. Merits and demerits of treatments in Kariguini

Treatment	Merits	Demerits
Mulch	• Easily available • Protects soil from direct sunlight • Preserves moisture • Increase soil fertility • Weed control • Control of aphids • Can be used many times	• Is dusty and can hurt the skin • Arsonists can burn your shamba • Can carry seeds for other weeds • Snakes and other reptiles can hide in it
Fleece	• Prevents aphids and all other insects • Higher yield • Can be used many times • Protects seedlings from the sun • Easier and moderated watering • Seedlings grew faster • Protected the seedlings against physical damage such as people stepping on them	• Not locally available • No knowledge of cost if it was available locally • Can not be used in the whole field • Can be stolen
Spraying	• Is easy to use • Can be used against many pests and diseases • Leaves of cabbages and kales are healthy	• Makes people sick-poisoning • Kills even the beneficial insects • Requires a lot of other accessories such as gloves etc • Destroys the soil • Pollutes the atmosphere • Are expensive • You can not access it unless you buy from the shop-have to use money • Low farmer knowledge of which chemicals are bad or good • Storing it in the house is risky.

3.6 Some achievements of the participatory budgeting exercise

3.6.1 Acquisition of record keeping skills by farmers

Alongside the budgets for the on farm trial, farmers were trained on how to keep their own farm budgets and facilitated to do so through provision of notebooks.

3.6.2 Farmer empowerment and ownership of the trial

Farmers felt they controlled part of the trial and as the scientists showed them how to recognize the disease, they had their own part of the trial; collecting and recording input data, timing of operations and monitoring the progress of the trial. Towards the middle of the trial, farmers were able to describe the trial activities to visitors and other scientists that came to see the trial.

Figure 2. Farmers explaining the on farm trial to visitors from NR International.

3.6.3 *Increase in number of participating farmers over the period of the trial*

There was an increasing level of participation by farmers through the period of the on-farm trial. In total 52 different farmers participated in the trial in Athi River. This coming together of farmers also created a forum for them to discuss other issues of common interest such as environmental issues, water use etc. By the end of the trial, the farmers decided to form a group and registered themselves in order to get more assistance from the government and other development agencies.

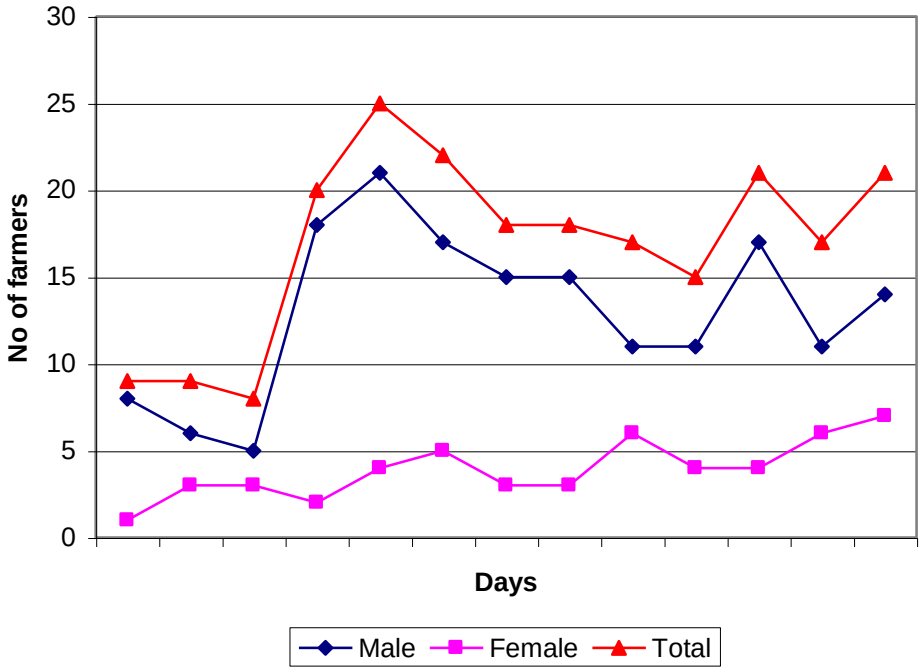

Figure 3. Farmer attendance to the on farm trials in Athi River

3.6.4 *Agreement by farmers to try the disease control strategies on their farms*

The two groups of farmers in discussion with the project team agreed to try the disease control strategies specifically the mulch and the fleece, on their farms during the next planting season. The project team will provide the fleece to the groups.

4. EVALUATION OF CHANGE OF FARMER PERCEPTION OF VIRUS DISEASES OVER PROJECT PERIOD

4.1 Objective

A final PRA was carried out with the aim of establishing how farmer perceptions of viral diseases and their management have changed over the period of the project. This was done with the groups involved in the on-farm trials. These groups were Ruiru, Athi River and Kariguini.

4.2 Methodology

The PRAs were called out in form of an individual questionnaire survey and focus group discussions with the group members. The questionnaire is attached as Appendix 3. Questions asked in the individual questionnaire survey included the symptoms of viral diseases, the four management strategies used as a control for viral diseases, the farmers perceptions' of the importance of viral diseases, whether farmers had used any of the management strategies and what problems they experienced, which pests and diseases still pose a problem in vegetable production and what farmers think they have gained from the project. During the group discussions, a format similar to that used in the initial PRAs was followed. Farmers were given leaves containing symptoms of viral disease and were told to identify the symptoms and what causes them. They were then asked to identify the management strategies and rank them again in order of priority. The farmers' perceptions and practices were then based on a wealth indicator using criteria earlier identified by farmers during the initial PRA.

A comparison was made between farmers' expectations at the beginning of the project and the achievements that they have made. Farmers gave a score out of 100 to the scientists based on whether they helped them achieve their expectations or not. The scientists gave scores to the farmers based on whether they thought farmers had met their expectations.

In order to avoid bias in answering the individual questionnaires, the individual surveys were carried out before the group discussions.

4.3 Results

4.3.1 Wealth ranking of the farmers

A wealth ranking as described by Bellon (2001) was used for categorizing the farmers into different wealth categories. Wealth is an important social category and varies from place to place. The wealth ranking was then used to analyze the preferences of farmers based on their wealth and their adoption of the disease management strategies. This is because the adoption of the management practices may be completely different between different wealth groups since each may control different sets of resources.

The indicators for the wealth ranking for the different groups from the initial PRA were used for Athi River and for Ruiru. Since an initial PRA had not been done in Kariguini, a new set of indicators was discussed.

The procedure followed was:

All the farmers' names were written on pieces of cards. Four farmers were then selected from the group as key informants. Those selected had good knowledge of the households represented in the groups. Both men and women were included in this group of key informants. The criteria for wealth ranking and the indicators for each of the wealth categories from the initial PRA were reviewed. Once everyone was conversant with indicators for each category, the names from the cards were read out a loud and the informants placed the farmer in a specific category. In case of discrepancy between the key informants, the indicators were reviewed again until a consensus was reached. All the farmers were then placed in respective wealth categories. In Kariguini since there were no indicators, an agreement was reached with the key informants on what indicators define a wealthy, poor and intermediate farmer. These indicators were then used to place the farmers in the different wealth categories. Out of the 34 farmers in the individual interview, 10 were in the low wealth category, 22 in the medium wealth category and 2 in the high wealth category.

4.3.2 Changes in farmer knowledge of viral diseases and their symptoms

When farmers were asked directly for the symptoms of viral diseases, 79% per cent of the

farmers were able to identify yellowing as a symptom of viral diseases while 26% identified leaf curling as a symptom of viral diseases. Other symptoms that farmers associated with viral diseases were leaf distortion, stunted growth, and aphids. Symptoms not mentioned by farmers included clearing of veins.

As groups, the farmers were given leaves of kale with various virus symptoms and told to identify the symptoms and what causes them. This was then compared to the results of the initial PRA.

Table 18. Symptoms and farmers perceptions of their causes

Symptoms	**Causes**
Athi River	
Leaf spots	Cold, Aphids
Curling of leaves	Aphids, cold
Yellowing	Low fertility, moisture stress
Clearing of veins	Do not know
Kariguini	
Curling of leaves	Aphids
Drying of leaf ends	Moisture stress, virus
Yellowing	Virus
Ruiru	
Vein clearing	Do not know
Yellowing	Aphids
Leaf curling	Aphids
Stunting	Diseases including viral

Although farmers in Athi River knew some of the symptoms of viral diseases, they did not remember the types of aphids and their relationship to viral diseases. Compared to the initial PRA when most of the farmers associated viral symptoms to either fertility or moisture stress, most of the farmers could now associate the symptoms of viral diseases to aphids.

4.3.3 Individual farmer evaluation of disease management strategies

Farmers ranked the disease control strategies according to preference. These have been compared across groups and across wealth categories. The high wealthy category was not included in this analysis as it had only two cases. In Athi River, most of the farmers (70%)

preferred spraying to the other strategies. Another 20 percent preferred fleece. Fleece was most preferred by the farmers in Kariguini and Ruiru with the lowest preference for spraying being in Kariguini.

The differences between these groups explain their preferences for the control strategies. Farmers in Athi River are purely commercial farmers, and for them the most available option is the most attractive irrespective of the environmental consequences. The fact that Athi River is near an urban center and pesticides are more available makes spraying more attractive than the other options. Kariguini, on the other hand is a group that has been growing vegetables organically and therefore spraying is not an attractive option for them.

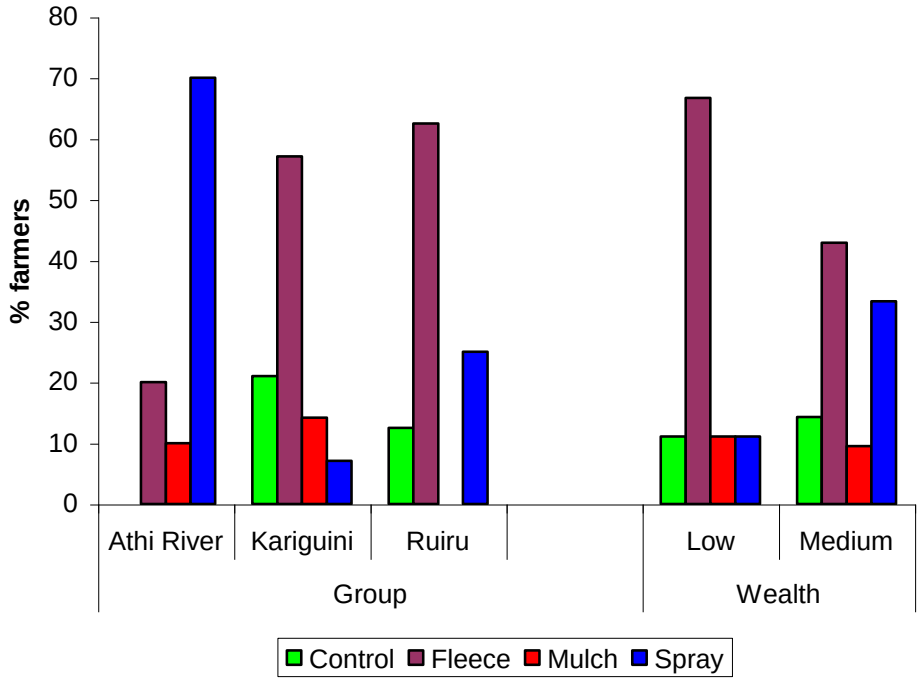

Figure 4. Percentage of farmers ranking each treatment first by group and wealth

The low wealth category preferred fleece with only 30% preferring control, mulch and spray. The medium wealth was split almost half and half between use of pesticides and fleece with just about 10% preferring mulch.

4.3.4 Final group evaluation of disease management strategies

In Athi River, the group ranked spraying top followed by mulching and fleece. The fleece was not available and farmers stipulated that even if it were made available in the country, it would still be expensive, as it would be sold as an imported product. Mulching was favoured as it serves different purposes including improving water retention in the soil and reducing the number of weedings as well as preventing viral diseases. It was however also scarce and farmers spent long hours looking for grass to cut and use as mulch. Out of the 7 farmers that had been given some fleece by the project, one had used it while the others had not planted their nurseries yet. Farmers felt that the fleece would save them some money since they would not have to spray in the nursery. It was safer to human health and the environment.

In Kariguini fleece was ranked highest followed by mulch and control. This being an organic group, they did not favour spraying due to its environmental and health effects. Since the majority of them depend on rain fed horticulture, none had used the fleece as they were still waiting for the rains.

In Ruiru, farmers ranked fleece highest followed by mulch, spraying and control. Although these farmers are more commercialized than the farmers in Kariguini, they are still willing to use fleece and mulch to reduce the cost of kale and vegetable production, especially in cases where they can get the mulch locally without having to purchase it. Those who had tried mulch, however, indicated they still had to use chemicals to control other diseases and pests.

4.3.5 Adoption

The adoption of these management strategies did not always follow the farmer preferences. The proportion of farmers who had tried any of the management strategies was compared across groups and across wealth categories. The results are shown in Figure 5.

Almost half of the farmers interviewed (41%) had tried one of the control methods. Most of the farmers had tried mulch. Others who indicated that they had sprayed were excluded from this analysis as spraying had been part of the farmer practice prior to the study. More

farmers had tried mulch in the low wealth category than in the medium wealth category. Although during the budgets the mulch treatment was more expensive than the spraying treatment, if farmers obtain the mulch locally, the treatment becomes more attractive especially to the low wealth category of farmers. A higher percentage of farmers in Ruiru mulched compared to farmers in the other two groups. This is despite the fact that none of these farmers had indicated mulch as their number one preference. In Kariguini, most of the farmers had not planted their nurseries as they practice rain fed vegetable production in contrast to farmers in Ruiru and Athi River who depend exclusively on irrigation. Problems encountered in the use of mulch included infestation by ants and termites, and unavailability causing farmers to spend long hours collecting the mulch.

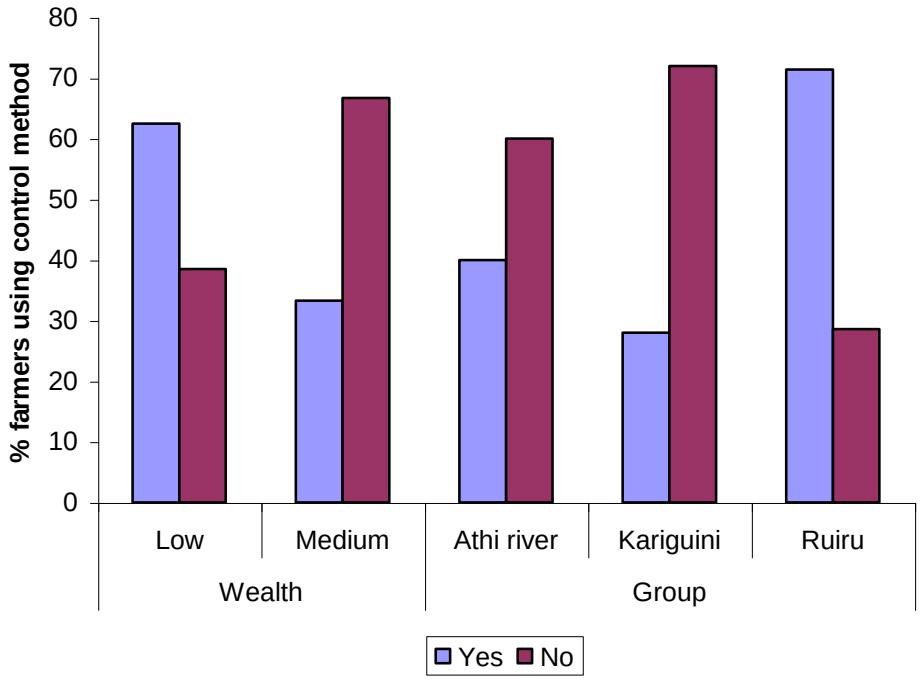

Figure 5. Adoption of disease control strategies

Adoption of fleece could not be evaluated since farmers had just received the fleece and therefore had not had the opportunity of using it. Fleece posed a problem as apart from that supplied by the project, it is apparently not locally available. It is this unavailability of fleece that may have prompted farmers who had preferred it to try mulch.

4.3.6 Farmers expectations from the project and their perceptions of how far these have been met

Athi River

1. **Improvement of farmers' income**

This objective had been 590% met according to the farmers. Some of the achievements were that the project team had made the farmers more cohesive by encouraging them to form and register a group, had provided knowledge on disease and pest control enabling farmers to reduce their costs of production. The farmers had also become model farmers for other farmers in the district. The group felt that we should have helped them more in terms of giving them loans, farm inputs including fertilizers, seeds and chemical sprays as well as farming equipment such as a pump.

2. **Visits and study tours**

The farmers expected the project team to take them for visits and study tours to see other groups of farmers more experienced in vegetable production and other institutions dealing with vegetable production and marketing. The project scored zero marks for visits and study tours.

3. **Increased knowledge of pests and diseases**

Farmers felt their knowledge had increased with respect to cabbage production, viral diseases of kale and cabbage, record keeping and group work. However, they felt that due to their multiplicity of problems, projects should not confine themselves to only one crop and only certain diseases but should deal with different crops, different pests and diseases and different aspects including marketing. In terms of knowledge on other aspects, the project scored 20%.

Kariguini

1. **Increased knowledge of pests and diseases**

Farmers gave the project 85% for giving them knowledge on pests and diseases in a practical and participatory way. Of importance to farmers was the knowledge gained in disease control at nursery level, general nursery management, fertilizer application and the importance of farmers planting their own nurseries. The farmers would however have liked to see the experiment through to completion or to visit the Athi River group who finished the experiment to the end**.**

2. **Good vegetable production**

The farmers gave the project 80% for trying with them alternative control strategies especially since they were an organic group trying to use less pesticide on their farms. Record keeping was also appreciated as the farmers could now keep their own records and budget for their activities.

3. **Follow up**

Farmers would have wanted to have a repeat of the experiment since they did not see the results and only discussed the results from Athi River with the project team.

Ruiru

1. **Improvement of farmers income**

Farmers' incomes have improved and the farmers gave the project team a score of 80% in this respect. They attributed this to increased awareness of diseases enabling them to control at nursery stage and therefore reduce damage to the crop. The farmers would have liked to repeat the experiment so as to see the final results.

2. **Follow up**

The project team got 60% for follow up as the group was taken to the KARI station for a study visit on vegetable production.

3. **Increased knowledge of pests and diseases**

The project team got 80% for increasing farmers' knowledge on disease and pest management and offering farmers alternative control and record keeping skills. They lauded the team approach of giving both theoretical information and putting it into practice with farmers in a participatory way, a especially including a farmer practice trial for comparison with the alternative management strategies. The problem, the farmers said, is that they are still experiencing problems with other pests and disease such as nematodes.

Other gains from the research as expressed by farmers included cost effective means of pest and disease control, good nursery management, good vegetable production including timing of fertilizer application, seedbed preparation, nursery preparation etc, record keeping, profitable farming and farmer empowerment.

4.3.7 Priority crops and pests for future research

Farmers in the three groups were asked for the priority crops, pest and diseases that they would like future research to focus on.

Table 19. Priority crops, pests and diseases for future research

Crops	**Pests and diseases**
Athi River	
Tomatoes	Spider mites
French beans	Early blight in tomatoes
Onions	
Kariguini	
Bananas	Fusarium wilt
Potatoes	Bacterial wilt
Maize	Maize streak virus
Ruiru	
Tomatoes	Spider mites
Capsicum	Nematodes
Coriander	Leaf curl

Management strategies that farmers would like research on include use of less pesticide and the effecting of burning debris and rotation on bacterial wilt of tomatoes and potatoes.

5. POTENTIAL FOR FARMER SELF SEED SELECTION

5.1 Objective

The objective of this study was to determine the potential for self-selection of seed of resistant/tolerant components of land races of kale as a strategy for disease management.

5.2 Methodology

Ten farms were selected in Kinale where farmers save their own kale seed. In these farms, healthy and diseased plants were identified and tagged. In order to link these with farmer participation, the 10 farmers were also asked to identify plants that they would consider suitable as planting material and plants that were unsuitable as planting material. These were tagged as good and bad. The disease free were tagged as healthy and infected ones were tagged as diseased. During the tagging process, farmers were also shown how to identify the viral disease symptoms. The criteria used by scientists and farmers to select the plants are given in Table 20.

Table 20. Criteria associated with good and bad plants for kale seed as selected by farmers and scientists

Farmer criteria		**Scientists criteria**	
Good for seed	**Bad for seed**	**Good for seed**	**Bad for seed**
Green leaves	Small seeds	Aphid infested but still healthy	Small seeds
Many thick, long ponds	Thin leaves	Healthy green leaves	Thin leaves
Late flowering (long harvest period)	Stunted plants	Late flowering	Stunted plant
Soil fertility of the area around the plant	Short and slender pods		Weak plants
	Leaf yellowing (chlorosis)		Short and slender pods
	Immature seeds		Leaf yellowing/chlorosis
	Aphid infested plants		Immature seeds
			Aphid infested plants

.

The seeds were then harvested and sowed at each of the farms in nurseries. Farmers were however not informed of which batch of seeds came from which category of tagged plants. An evaluation was done with farmers after 2 weeks and again after 4 weeks. The farmer was asked to allocate points to each of the treatments for each evaluation category from a total of 20 points for each evaluation criteria. The treatments were evaluated for germination time, % germination, colour, height, disease and pests. The evaluation sheet is given as Appendix 4. During the first evaluation none of the farmers were able to tell the disease symptoms on the kale seedlings while only 3 were able to do during the final evaluation. During these two evaluations, the identity of the treatments was not disclosed to farmers.

5.3 Results of the evaluation

Figure 6 below gives a summary of the results of the evaluation after 4 weeks. In terms of germination time and the % germination, the farmer selected good seed had the highest points allocated. Scientists selected good seed scored the highest for crop colour, crop diseases and crop pests while the highest score for crop height was given to the farmer selected good seed. In summary, the scientists' selected good seed and the farmer selected good seed were the best placed treatments as compared to the scientists' selected bad seed and the farmers' selected bad seed.

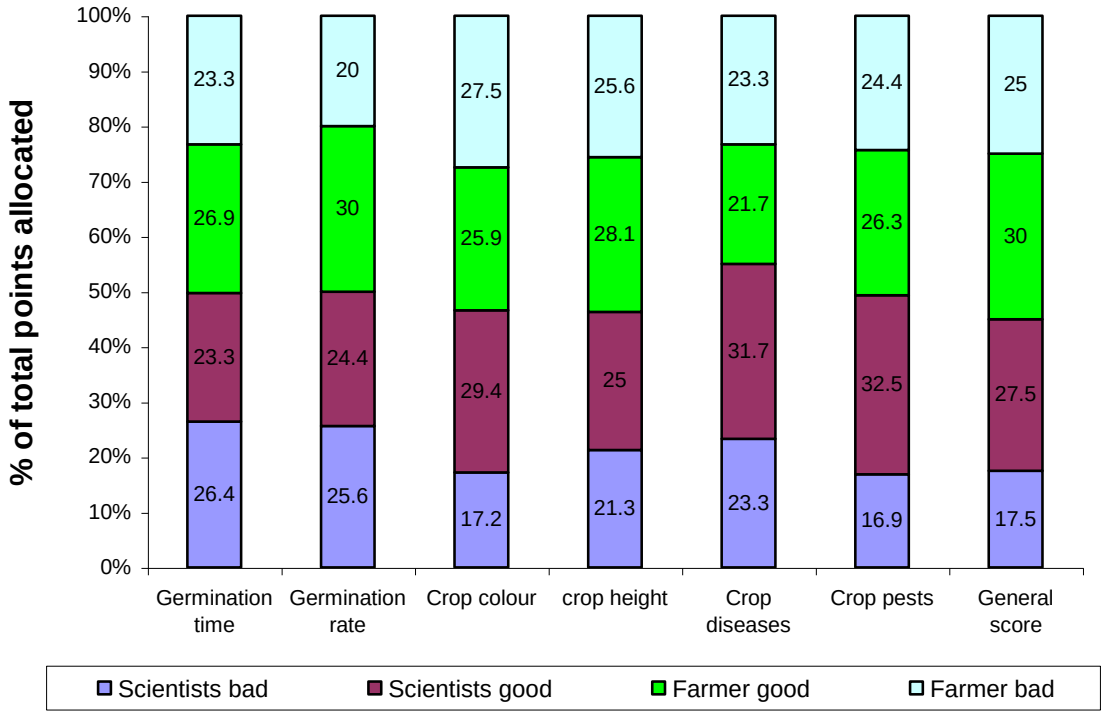

Figure 6. Evaluation of on farm seed selection by farmers

5.4 Field day to sensitize farmers on farmer self seed selection

In order to reach more farmers, a field day was organized in one of the selected farms. During the field day the on farm trial was explained as a way to enable farmers to select promising seed from kale that is resistant/tolerant to brassica viruses. The criteria used to select healthy and diseased land races by farmers and by scientists were revisited for the benefit of farmers who were not in the trials. A demonstration was then carried out on viral disease identification. Farmers were also taught about the transmission of viral disease by aphids and the different types of aphids. The three types were shortened for farmers as Brevi for Brevicoryne brassica, Myzus for Myzus persicae, Lipa, for Lipaphis erysimi.

A total of 19 farmers attended the field day together with 3 staff from CABI-ARC and 4 from KARI.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Evaluation of viral disease control strategies by farmers

The disease control strategies were well received by the three groups of farmers. The choice of each group depended on the type of group and their circumstances. The commercial farmers mainly in Athi River preferred spraying pesticides as opposed to using fleece and mulch. These are farmers who have rented small pieces of land for vegetable production and mulch availability is low. Those farmers who could obtain mulch tried it on their farms. In Ruiru, farmers preferred mulch as they have bigger pieces of land and they can obtain mulch locally. Kariguini who are organic farmers, preferred fleece and mulch and even the control treatment to spraying. These strategies were associated with several advantages and disadvantages. Fleece kept the vegetables protected from all other pests but was not locally available. Mulch on the other hand was favoured as it served other purposes including weed control, preserving soil moisture, controlling pests, and adding organic matter to the soil. It was, however, associated with fires and was also hard to find locally, especially for farmers with small land sizes.

The implications of this evaluation are that before any technologies/strategies are recommended to farmers, farmers need to be given a chance to evaluate them and assess their suitability. Farmers will then have a choice on which management strategy is most appropriate for them depending on their circumstances. For farmers to do this, they need to be equipped with skills to enable them to do an informed evaluation. Skills such as record keeping and budgeting proved to be very useful during this evaluation as farmers were able to cost each of the strategies as well as to compare the returns from each. A two-season evaluation would be desirable for farmers to make across season evaluations of the strategies.

Given the high preference for fleece, arrangements need to be put in place, preferably in collaboration with either the private sector or a local NGO for the local supply of fleece to farmers or to explore the possibility of a local alternative which can function as effectively as the fleece.

During the final evaluation to assess impact of the project, more than 40% of those farmers that had been involved in the evaluation had tried the disease control strategies of their choice on their farms. The potential for adoption was even higher since the evaluation was done in the dry season before farmers had made their nursery beds. There was an indication that more farmers

would adopt the strategies, especially mulching and the fleece provided by the project.

6.2 Change of farmer perception and knowledge of viral diseases

During the initial PRA the farmers' perception of viral diseases was very low. Only one farmer in all the three groups attributed viral disease symptoms to aphid attack. Other farmers associated viral symptoms to moisture stress, low fertility, too much watering, potassium deficiency and even excess use of manure. These causes were sometimes contradictory indicating the very low knowledge farmers had on these symptoms and their causes. Asked for the control of these symptoms, the farmer response was always spraying. Farmers did not have any other alternative control. After the on farm trials, farmers were able to associate the symptoms to viral diseases and more important, farmers were able to associate these symptoms to aphids.

6.3 Potential for on farm seed selection

Seeds from both the farmers' and scientists' selection of good plants outdid the seed from bad plants in terms of germination time, germination percentage, crop colour, crop height pests and diseases. Farmers were trained on viral disease identification in order to combine their criteria for seed selection with the scientists' criteria of disease free plants. With this knowledge, the potential for seed selection in Kinale has increased. However, for farmers to benefit economically from this, the seed market systems need to be streamlined to avoid exploitation of the farmers by middlemen.

APPENDICES

Appendix 4a. Check list for PRA on vegetable virus control for smallholder farmers

- A wealth ranking to get different social categories of farmers
    - Develop indicators of wealth
    - Assign values to different indicators for different social categories-rich, poor and medium.
- General problems and constraints in vegetable farming (List)
    - Farmer priority constraints in vegetable farming (Rank)
- Priority pests and diseases
- List and rank important and common land races of kale and cabbage
- Disease and pest calendar for cabbage and kale
    - For each of the crops, kale and cabbage, identify different growth stages of the crop, the symptoms of either pests or diseases observed in each, what farmers attribute the symptoms to, the control methods and rank land races according to susceptibility to these diseases/symptoms.
- A general discussion of the problems and constraints of the control methods mentioned above.
- Pick out from table the control methods used for viral diseases and symptoms and for aphids and rank them in terms of
    - Effectiveness
    - Cost
    - Availability
    - Practicability
    - Environmental and personal safety

Appendix 4b. Farmer indicators of wealth

ATHI RIVER			RUIRU		
Rich	**Medium**	**Poor**	**Rich**	**Medium**	**Poor**
6-20 grade cows	1-5 cattle	No cattle	Multi-storey house with tiled roof	Stone walled house with iron sheet roof	**Brick walled house with iron sheet roof**
11-50 goats	6-10 goats	0-5 goats	1 to 2 motorcars	One bicycle	1 wheelbarrow
Hire land of 4 and above acres	Hires land of ½ to 3 acres	No land-Squatting	**3 acres of vegetables, access to fertilizer and quality seed**	**1 acre vegetables, not enough fertilizer or quality seed**	No inputs, borrows seeds and no fertilizer applied
House with stone wall and iron sheet roofing	House with iron sheet wall and roof	Paper house	50 hp irrigation pump, tractor, sprinklers	**3-4hp irrigation pump, no tractor, no sprinklers and uses pipes**	**Bucket irrigation or money maker**
Has access to irrigation water	**Has access to irrigation water**	**No access to irrigation water**	Has hired labour	Uses own labour or casual	Uses own labour only
Has irrigation equipment	Rent or borrow irrigation equipment	No irrigation equipment	**2-5 grade cows, no local cattle**	1 grade cow or 3-15 zebu animals without grade cows	0-2 local cattle
Has permanent hired labour	**Uses own labour and sometimes hires**	**Provides own labour**	Children attend private boarding school	Children attend local government school	Children do not attend school
Grows irrigated crops for export-French beans, flowers, okra etc	**Grows irrigated maize, kales, beans, French beans, cabbage, tomatoes and chillies for local market**	**Grows rain fed maize, beans and kales**	**Meat in diet everyday**	**Meat in diet once a month**	No meat in diet

Has enough operating capital	Minimum operating capital	No operational capital	**30,000 Ksh and above operating finance**	Ksh 5-30,000 operating finance	Ksh 5000 and below operating finance
Have modern farming experience or hire experienced managers.	Uses traditional and modern farming experience	**Uses traditional farming experience**			

Appendix 4c; Evaluation questionnaire

Farmer Name……
Wealth category (defined by farmers)……

Knowledge of viral diseases and their management

1. What are the symptoms of viral diseases on kale/cabbage? Give two
   i) ……
   ii) ……

2. What management strategies have we experimented on? Give all four
   i) ……
   ii) ……
   iii) ……
   iv) ……

3. Rank the above strategies starting with the best *(rank only what the farmer has identified above)*
   i) ……
   ii) ……
   iii) ……
   iv) ……

Experimentation with disease management strategies

4. Have you tried any of the strategies we have experimented on in your farm? **YES/NO** (circle)
5. If yes, which one?……..
6. Did you have any problems with the management strategy that you have tried on your farm? **YES/NO** (circle)
   If yes, what?
   ……
   ……

Change in importance of viral diseases as a constraint to vegetable production

7. Could you rank the symptoms on your farm now starting with the worst?
   1. ……..
   2.……
   3.……

Other gains from the on farm evaluation

8. What would you say is the most important thing you have gained from our collaboration in these trials?
   ……
   ……..

The future

9. Are there other crop diseases or pests and their management strategies that you would like us to research on together with you?

Disease/pest **Management** **strategies**

Appendix 4d. Form for evaluation of self-seed selection by farmers
Farm No……
Name of farmer ……..……

Procedure for evaluation

4. For each of the evaluation criteria, give a total score of 20.
5. Ask the farmer to give each of the treatments a score out of the 20 (To allocate the 20 scores to the 4 treatments.)
6. Ask the farmer to combine all the criteria and give a general score for each of these treatments (these scores must also add up to 20)

Treatment	**Treatment identity (not to disclose to farmer))**	**Germination time**	**% Germination**	**Colour**	**Height**	**Disease**	**Pest attack**	**General appearance**	**General score**
T1									
T2									
T3									
T4									
Total		20	20	20	20	20	20	20	20

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Appendix 4e. Disease calendars for Kales and cabbages in Athi River and Ruiru - Kales

Athi River					Ruiru					
Growth stage	Symptoms	Disease or pest (farmer)	Disease or pest (actual)	Control	Growth stage	Symptoms	Disease or pest (farmer)	Disease or pest (Actual)	Control	Most susceptible
Nursery	Whitish rusty leaves	Blight	1000 headed	Ridomil Dithane Antracol	Nursery	Leaf perforations	Green or black caterpillars	Diamond Back Moth	Dimethoate Karate Marshal Diazinon Bulldock Fastac	1000 headed
	Rotting of roots	Whitefly	1000 headed	Karate Dimethoate Polytrin		Fine leaf perforations	Adults of the green caterpillars	Diamond Back moth	Same as above + thuricide and Lannate	1000 headed
	Drying on stem base	Cold	1000 headed	As blight		Rotting stem	Cold		Ridomil copper	1000 headed
	Leaf perforation	Caterpillars Leaf hoppers	1000 headed	Karate Dimethoate Thuricide		Stunted growth	Low quality seed, poor soil		None	1000 headed
	Curling of leaves	Aphids	1000 headed	Karate Dimethoate		Eaten leaves	Birds		Scare	All
						Wilting	Nutrient deficiency		None	
Seedbed	Drying of stem		1000 headed		Seedbed	Small perforations	whitefly		Thuricide	1000 headed
	Yellowing and drying of stem and roots		1000 headed			Curling of leaves	aphids		Dimethoate Karate Dry ash	1000 headed
						Stem rot & drying	Caterpillars		Remove and kill	1000 headed
						Yellowish rough leaves	Cold		Ridomil Karate Dimethoate	1000 headed
						Black leaf veins	Cold		Ridomil Karate Dimethoate Uproot	1000 headed
						Whitish powder on underside of leaves	Fly (type not specified) Sunny conditions Insufficient water		Thioviate	1000 headed

						Yellowing and drying of leaves	Mites		Dimethoate Karate	1000 headed	

Cabbages

Farmers agreed that in the nursery, the diseases and pests that attack kales are the same ones that attack cabbages. However in the seedbed, apart from those attacking kales, there are other pests and diseases that are specific to cabbages.

Athi River					Ruiru				
Growth stage	Symptoms	Disease or pest (farmer)	Disease or pest (Actual)	Control	Growth stage	Symptoms	Disease or pest (farmer)	Disease or pest (Actual)	Control
Seedbed	Curling of leaves	Aphids		Dimethoate	Seedbed	Cabbage heads not forming	Sunny conditions Insufficient water		
	Leaf perforations	DBM				Yellow spots on leaves	Cold		Copper
	Stem rot			Uproot		Black ring on stem leading to drying	Lack of crop rotation		
						Head rot from top	Water collecting on cabbage Worm/aphids inside during head formation		Uproot

Appendix 5

Rural rapid appraisal on kale seed selection/in choice

KINALE DIVISION, LIMURU DISTRICT.

BY
WACHIRA S. W.

11th April, 2001

Introduction

The peri-urban area is major source or horticultural produce for the urban folk. Thus rapid increase in population in the urban area means a larger market for the fresh produce from the surrounding farms. This will encourage even the small scale producers to venture into horticultural production.

SURVEY FINDINGS

kale production in Kinale division is mainly done at small scale level whereby the main source of labour is the family. Hired labour is only used during the peak production times. These are during the rainy periods. This is the case because the area is mainly dependent on rainfed agriculture. Farmers are not aware of any specific varieties of kale, and are not able to identify the varieties suitable to their area.

kale seeds are produced by farmers mainly on-farm. Alternatively, they buy seed from neighboring farmers or in the market. This is because on-farm seed is cheaper to produce and gives a better assurance of the expected production. This is made possible by the general criteria used to select plants to be used for seed production.

Criteria for selection of kale plants for seed production

- Are the last to flower (long harvest period)
- Have healthy and strong stem and leaves
- Are not diseased or insects infested
- Produce a good crop

After identification, the plants are let to flower and when the pods are mature and ripening they are harvested, dried and thrashed, thus, ready for use in the farm. Some farmers leave their plants to flower and use that as animal feed.

Seeds availed in the market by various seed companies does not to meet their required standard for the mainly small scale farmer who wants to fetch maximum output from the crop because of the following reason:

- has stunted growth
- flowers with just a few pickings meaning its production life span is short
- is more prone to diseases
- is expensive as compared to seed sold in the market

None of the farmers are large scale producers of kale seed but produce for their own consumption with what is left over being sold or stored for future use.

No major diseases/pests were highlighted in relation to seed production as only clean plant materials are selected. In kale production however, many of viral diseases that were identified, were spread by the major pests which are aphids and diamond moths. It should be noted that the farmers are not keen on taking up any high cost pest and disease management strategies. This is because the returns from kale sales are too low to meet these costs as well as realize profit for the farmer.

Market issues for seed are not important as they only produce for own use or sale at farm gate and it is also possible to store the seed for future use. On the other hand, there are major in kale marketing because of exploitation by middlemen who take advantage of the poor infrastructure to offer very low prices for the produce. The farmer should be encouraged to form small co-operatives that will enable them exercise their collective bargaining power and fetch better prices for their produce. When this is carried out the farmer will now be willing to invest more resources in kale production thus improving quality and quantity of output.

Farmers are well conversant with soil management practices that are suitable for kale production. The use of both manure and fertilizer for those whose farms are near their homesteads was rampant. Farmers who had hired land that was a distance from the homestead use only fertilizer. The reason for this was that manure is too bulky to transport for a long distance. The farmers who used manure were mainly those who had animals because the price of manure is too high as opposed to that of fertilizer.

CONCLUSION

Improved production of kale is possible if and only if the economic returns to the farmer are improved, seeds from companies are given specific standards to meet and pest and disease management strategies that are cost effective are availed to the farmers. Collaboration among all concerned parties should be ensured.

Appendix 6
Visit to Kenya for Stakeholders Workshop and field visit to Nyathona to observe virus diseases of *Brassica* and spinach

FILE NOTE

(Visit Number VS)

Visit to Kenya for Stakeholders Workshop and field visit to Nyathona to observe virus diseases of *Brassica* and spinach

N J Spence and D M Teverson

File circulation	**Loose copy**	**Separate copies**
1. Prof. R J Cooter	1. Dr R Hillocks	1. Dr S Eden-Green
2. Dr N J Hayden	2. Richard Lamboll	2. Prof. J M Lenne
		3. Dr N J Spence

Background

1. The project ZA0376 "Management of virus diseases of vegetable crops" has been accepted by NRInternational for DFID funding pending signing the contract.

2. Virus diseases of *Brassica* crops are widespread in PU vegetable production in Kenya but it is not known how significant yield losses might be. The proposal aims to develop improved methods for the control of virus diseases, in particular CaMV and TuMV in brassica crops in the PU vegetable systems being studied within the PU vegetable project cluster in Kenya. Virus control is to be achieved through identification of virus-resistant germplasm, cultural control methods to reduce virus incidence and spread, and improved vector control. The NRI contribution to the project will focus on farmer perceptions and practices that will be assessed in relation disease management.

3. A stakeholders' workshop was held in Nairobi at KARI NARL, with a visit to Nyathona to observe virus diseases of *Brassica* and spinach. It was the first opportunity for all the stakeholders to discuss project activities in detail, both to plan and co-ordinate activities.

Objectives

- To introduce project stakeholders to each other and encourage co-ownership of the project.
- To systematically discuss each of the project activities in detail and finalise i) what should be done, ii) how it should be done and iii) who should do it. As this project is part of a PU cluster it was also important to establish how the project activities could complemet the other projects.
- Some project stakeholders visited Nyathona to observe virus diseases of *Brassica* and spinach and to start survey and collection of virus infected samples.

Activities and Achievements

Drs Nicola Spence and Dawn Teverson had meetings with key CABI and KARI to discuss progress and finalise plans for research activities. They visited the NHRC at Thika to discuss location of the screenhouses for on-station trials and visited Nyathona to observe virus diseases of *Brassica* and spinach and start collection of samples infected with viruses.

Itinerary

Sat 19 Feb 2000	Leave UK for Nairobi, Kenya
Mon 21 Feb 2000	All day meeting with project stakeholders
Tues 22 Feb 2000	Maating with CABI/KARI virologists, visi to NHRC, Thika
Weds 23 Feb 2000	Visit farmers' fields at Nyathona, wrap up session at CABI
Weds 23 Feb 2000	PM travel to Entebbe, Uganda

Workshop participants

Valerie Palapala	***KARI,NARL, Box 14733, Nairobi***
Z M Kinyua	***KARI, NARL, Box 14733, Nairobi***
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Appendix 7

A survey of vegetable (Brassicas) viral diseases in the peri-urban systems

Valerie Palapala, March 2000

Visits were made to various peri-urban farms and viral diseased brassicas (kale, cabbage and cauliflower) collected. For each vegetable type, viral diseases symptoms on the collected samples were recorded, the percent virla incidence in each brassica crop estimated and each sample designated a specific collection number (Table 1). Other vegetables and crops grown on the farms were also recorded. Generally viral disease symptoms were observed in all types of vegetables for example coriander, *Capsicum*, tomatoes and *Cucurbita*. Tomato leaf curl, leaf roll and mottling incidences were unusually high in Nyeri with some farms recording 100% infection.

In the field, infected plant leaves with classical virus symptoms were placed between two moist filter papers and stored in a cool box. In the laboratory each sample was divided into two. One portion was placed in tubes containing fused calcium chloride to dry. The second portion was homogenised in 2-3ml of 1% di-potassium hydrogen phosphate buffer containing 0.1% di-sodium sulphite solution. The resultant supernatant was divided into three portions, placed in microcentrifuge tubes (1.5ml) and stored at -40°C in a freezer. Inoculations were carried out using viral suspensions prepared by placing 20µl in 0.5ml distilled water. Ordinary "scotch brite" was used as an abrasive to aid in application of the viral suspension onto leaf surfaces. Isolate used for inoculation purposes included:1, 5, 9, 12, 13, 15, 18, 21, 26, 29, 32, 34, 35, 38, 39, 41, 43, 45, 46, 47, 49, 51, 53, 54, 59, 61, 62, 65, 67, 69, 72, 75, 77, 78, 79, 82, 84, 90, 91, 93, 97, 99, 102.

Table 1 Summary of a survey of *Brassica oleracea* (cabbage, kale and cauliflower) viruses in the peri-urban farming system

Farm	Sampling site	Symptoms observed and estimated % viral disease incidence	Other crops grown on farm
Farm 1 – Mr Chacha	Nyathona	Kale: 70% incidence on 2 month old local kale variety. Vein clearing, mosaic, leaf curl, severe chlorosis and leaf distortion. Severe DBM and *Brevicoryne* infestation (#1); 1 month old seedlings were chlorotic, had vein clearing, stunted (#2); #3 and #4 had vein clearing, chlorosis and *Brevicoryne*. Cabbage (Gloria F1): Chlorosis, vein clearing (#5)	Pepper, cabbage, maize, spinach (nursery), potatoes, lettuce, cauliflower (seed bed), coriander and beans
Farm 2 – Mrs Gathura	Nyathona	Spinach: 90% incidence. Severe chlorosis & mottling (#6); #7 was chlorotic Kale: Chlorosis & vein clearing (#8 & #9). Cabbage: 70% incidence. Vein clearing, chlorosis, purpling of vein ends (#103). Cauliflower: 60-70% #104 leaf distortion, vein distortion & clearing, severe chlorosis, *Brevicoryne*. #105 leaf distortion and mosaic. #106 leaf distorion, necrosis, chlorosis & vein clearing. #107 leaf distortion reduced leaf size, necrotic spots, severe chlorosis and *Brevicoryne*.	Coriander, spinach, onions, cauliflower & lettuce
Farm 3 – Mr David Karuga	Nyathona	Local kale variety: 60% incidence. #10 was *Brevicoryne* infested, chlorotic, mosaic and leaf distortion; #11 was chlorotic, vein clearing, mosaic and slight leaf distortion; #12 mosaic, vein necrosis & chlorosis. #111 & 112 – clean samples amongst viral infected plants. 3 month old cabbage: vein clearing, chlorosis and *Brevicoryne* (#13) Coriander (3 weeks) chlorosis, rosetting, vein clearing & stunting. Cauliflower: less than 5% incidence in the seedbed. #108 & #109 both had chlorotic spots. #110 severe chlorosis and vein clearing.	Bananas, napier, onions, mangoes, spinach, lettuce, coriander & cauliflower (in seedbed)
Farm 4 – Mungai Kuria	Nyathona	Cabbage: 50% incidence. #15 chlorosis, leaf distortion & vein clearing; chlorosis, leaf distortion and *Brevicoryne* infested (#16). Kale: 70% incidence; #17 – severe *Brevicoryne* infestation, leaf distortion, chlorosis, vein clearing; #18 – mosaic, narrow leaf and chlorosis; #19 – severe leaf distortion, *brevicoryne*, chlorosis & vein clearing.	Peppers (100% viral ioncidence), spinach, coriander, onions, bananas & lettuce
Farm 5 – Geoffrey Njoroge	Kinale	Cabbage: 10% incidence; #20 had leaf distortion and chlorosis DBM and *Brevicoryne* infested; #21 – vein clearing, chlorosis and leaf distortion. Kale: 60% incidence; #22 – leaf distortion, vein clearing & chlorotic. #24 – leaf purpling & distortion, chlorosis & *Brevicoryne* infested. #24 – chlorosis, mosaic, vein clearing & reduced leaf. #25 – *Brevicoryne* infested, leaf distortion & chlorosis. #26 – leaf puckering & distortion, chlorosis, vein clearing & *Brevicoryne* infested.	Spinach, carrots & potatoes

Table 1 contd Summary of a survey of *Brassica oleracea* (cabbage, kale and cauliflower) viruses in the peri-urban farming system

Farm	Sampling site	Symptoms observed and estimated % viral disease incidence	Other crops grown on farm
Farm 6 – Gilbert Mwangi	Kinale	Cabbage: less than 10%; #27 – chlorosis, vein clearing & leaf distortion; #28 – stunted, leaf distortion & slight chlorosis; #29 – slight purpling, chlorosis & slight leaf distortion. Kale: distorted leaf, yellowing, vein clearing and *Brevicoryne* infested (#30). #31 – leaf chlorosis, stunted vein clearing and DBM infested. #32 – severe chlorosis, vein clearing & leaf distortion. #33- chlorosis, vein clearing & *Brevicoryne* infested.	Leeks, kale, onion, spinach, carrots, cabbage & potatoes
Farm 7 – Paul Macharia Muigai	Kinale	Cabbage: less than 1% viral infection. Significant cabbage ringspot infection (with many local necrotic lesions). Generally a very healthy crop. #34 – vein clearing and chlorosis. #36 – chlorosis, leaf distortion & slight *Brevicoryne* infestation. Kale: 5% incidence. Many DBM adults. #35 – chlorotic.	-
Farm 8 – James Njagi Thiaka	Mwea (Kimbamba)	Kale (1000 headed) intercropped with beans; 30% incidence. #37 – chlorosis, reduced leaf, severe DBM infestation and leaf distortion. #38 – mosaic, distorted leaf & chlorosis & severe DBM infestation.	Maize, pigeon peas & beans.
Farm 9 – Francis Kireri	Mwea	Kale: 20% incidence. Severe DBM infestation, chlorosis, swollen veins, vein clearing & distorted veins (#39). #40 – chlorosis & yellowing.	Maize, bananas & onions
Farm 10 - Mungai	Embu	Cabbage Gloria F1 variety: 60% incidence. Head distorted, chlorosis, leaf severely distorted, leaf puckering & vein clearing (#41). #42 – *Brevicoryne* infested, chlorosis, vein clearing, necrotic spots. Kale: 30% incidence. #43 – distorted leaf, marginal chlorosis & chlorotic spots on the leaf. #44 – chlorotic spots, DBM infestation.	-
Farm 11 – Kamuithi Mwinyi	Embu	Kale: 50% incidence. Severe leaf distortion, vein clearing, chlorosis & *Brevicoryne* infested (#45). Cabbage: 70% incidence. #46 – chlorosis, leaf distortion, vein clearing, chlorotic spots on the leaf.	Papayas, arrowroots, maize & cane.
Farm 12 - Murimi	Mwea West (Riambogo)	Cabbage (Copenhagen): 30% incidence. #47 – severe DBM infestation, yellowing, leaf defoliation, vein clearing, *Brevicoryne*, *Lipaphis* and DBM infestation. Kale: 60% incidence. Distorted leaf, mosaic & chlorosis (#48). #49 – severe chlorosis, reduced leaf surface & yellow striping.	French beans, cane & sorghum.
Farm 13 – Elijah Njogu	Giachia (Ndia division)	Tomato: 100% leaf roll incidence. Kale: #51 – foliar chlorosis.	Bananas, coffee, tomato & maize

Farm 14 – Samuel Mugo	Kaitheri (Kerugoya – Kirinyaga)	Kale: severe DBM attack, *Brevicoryne*, *Lipaphis*, *Myzus*, chlorosis & vein clearing. #53 – severe DBM, *Myzus*, *Lipaphis*, vein clearing & chlorosis.	Coffee, tomato, spinach, bananas & carrots.

Table 1 contd Summary of a survey of *Brassica oleracea* (cabbage, kale and cauliflower) viruses in the peri-urban farming system

Farm	Sampling site	Symptoms observed and estimated % viral disease incidence	Other crops grown on farm
Farm 15 – Muchina Karong'o	Mathira (Nyeri)	Kale (collard): 95% incidence. #54 – mosaic, chlorosis, vein clearing. #55 – chlorosis, *Myzus*, *Brevicoryne*. #56 – chlorosis, vein clearing, *Myzus* & *Brevicoryne*. #57 – leaf purpling (marginal).	French beans, cane, tea & tomato.
Farm 16 – Kiruiru wa Kamuyu	Karatina	Kale: 70% incidence. #58 & 59 – chlorosis, reduced leaf surface, vein banding, *Brevicoryne* & DBM infested. Cabbage: 95% incidence. #60 – chlorosis, vein clearing, leaf distortion, *Brevicoryne*, *Lipaphis*, *Myzus*, chlorosis, yellowing and vein clearing.	Bananas, maize, cane & peppers.
Farm 17 – John Maina	Guti (Karatina – Mathira)	Cabbage – Gloria F1: 100% incidence. #62 – distorted leaf, chlorosis, DBM & *Lipaphis* infested. #64 – chlorosis & *Brevicoryne* infested. Cucurbita: #63 – chlorosis, vein clearing & mosaic	Bananas
Farm 18	Giti (Karatina – Mathira)	Cabbage Gloria F1: small sized leaf and chlorosis (#65). #66 – chlorosis, distorted leaf & DBM infested.	Carrots, peppers.
Farm 19 – Dr Maina	Kamuyu - Nyeri	Cabbage: #67 – chlorotic & severe DBM infestation. #68 – chlorotic spots & severe DBM attack. Pepper: 80% incidence. Leaf puckering & curling (#69).	Papayas, bananas.
Farm 20 – Kinguru Gatimbia	(Kibirigwi)	Kale: 50% incidence. #70 – vein clearing, distorted veins, chlorosis, *Brevicoryne* and DBM. #71 – yellow spots & chlorosis. #72 – chlorosis, distorted leaf & vein clearing. #73 – *Brevicoryne*, distorted leaf, chlorosis & vein clearing.	Maize, spinach & tomato.
Farm 21 – Francis Kamungu	""	Kale: 40% incidence. #74 – vein chlorosis & *Myzus*. #75 – leaf curl, chlorosis, leaf distortion & *Myzus*.	Tomatoes & beans.
Farm 22	""	Kale: 10% incidence. #76 – chlorosis, veinal clearing & *Myzus* attack. #77 – *Lipaphis*, vein clearing & chlorosis.	
Farm 23 – John Kimiti	Mukuha	Kale interplanted with cabbage. #78 – vein clearing & chlorosis. Cabbage: chlorosis, vein clearing, severe DBM & *Myzus* attack (#79). Tomato: leaf curl, distorted leaf (#80).	

Farm 24: Gachero (Gachoka Ltd.)		Kale: 40% incidence. #81 – vein and leaf chlorosis, DBM. #82 – leaf puckering (varietal), *Myzus* and veinal purpling. Cabbage: 80% incidence. #83 – yellowing, *Brevicoryne* & *Myzus*. #84 – slight marginal & veinal chlorosis.	Spinach, bananas, onions, maize, potatoes, cowpeas & sweet potatoes
Farm 25 – Mary Njoka	Gatanga	Kale: #85 – vein chlorosis & mosaic. #86 veinal chlorosis, yellowing, leaf distortion & purpling. Sweet pepper: #87 – chlorotic patches & mosaic. #88 – severe leaf distortion, leaf mottling & leaf curl.	Maize & cane

Table 1 contd Summary of a survey of *Brassica oleracea* (cabbage, kale and cauliflower) viruses in the peri-urban farming system

Farm	Sampling site	Symptoms observed and estimated % viral disease incidence	Other crops grown on farm
Farm 26 – Joseph Maweru Kariuki	Karuri sublocation (Mangu location)	Kale: 20% incidence. #89 – clean kale. #90 – veinal chlorosis & purpling & *Brevicoryne*. Cabbage: 50% incidence. Chlorosis, *Brevicoryne* (#91).	Sunflower, tomato, bananas, capsicum, onions & roots
Farm 27 - Momanyi	Ngong’	Kale: 20% incidence. #92 – veinal chlorosis. #93 chlorosis, vein purpling, distorted leaf & slight DBM infestation. #94 – vein clearing & chlorosis. #95 – severe leaf distortion, chlorotic patches & vein clearing.	Tomatoes, oranges
Farm 28 –John Kamau	Kiserian	Kale: 80% incidence. Chlorosis & vein clearing (#96). #97 – vein clearing & chlorosis. #98 – severe DBM infestation, chlorosis & vein clearing.	Tomatoes
Farm 29 – Simon Mang’ehi	Kiserian	Kale: 60% incidence. #99 – localised chlorosis & vein clearing. #100 – foliar chlorosis & *Brevicoryne* infested. #101 – chlorosis.	Tomatoes, bananas, french beans, mangoes & onions.
Farm 30 – Bernard Muthe	Athi RIver	Kale (a very old crop): 20% incidence. #102 – chlorosis and vein clearing. #103 & 104 – chlorosis.	
Farm 31 - Kabiero	Nyathona	Cauliflower: 100% viral incidence. #113 – reduces leaf size, vein clearing, chlorosis, leaf distortion. #114 – severely distorted, severe chlorosis, vein clearing & *Brevicoryne*. #115 – severely distorted, reduced leaf size, severe chlorosis & vein clearing. #116 – chlorotic spots, slight vein clearing, chlorotic spots. #117 – mosaic & *Brevicoryne*.	Cabbage, kale & peppers.

Appendix 8

Internal Reports

Back to Office Reports
Spence NJ and Hughes SL. Visit to Kenya for project activities and field visits, 21 Oct – 28 Oct 2000 (Project No. ZA0376; R7571).

Spence NJ and Hughes SL Visit to Kenya for project activities and field visits, 8 April – 20 April 2001 (Project No. ZA0376; R7571).

Hughes SL Visit to Kenya for project activities and field visits, 3 November – 9 November 2001 (Project No. ZA0376; R7571).

Hughes SL Visit to Kenya for project activities and field visits, 8 December – 16 December 2001 (Project No. ZA0376; R7571).

Spence NJ and Hughes SL Visit to Kenya for project activities and field visits, 13 May – 17 May 2002 (Project No. ZA0376; R7571).

Phiri NA and Chacha D. Visit to HRI, UK for training, 7 – 26 July 2002 (ZA0376, R7571)

Quarterly Reports
Quarterly Report. 1 April 2000 - 3 June 2000.
Quarterly Report. 1 July 2000 - 31 September 2000
Quarterly Report. 1 October 2000 - 31 December 2000
Quarterly Report. 1 January 2001 - 31 March 2001

Project Progress Reports
Project Progress Report 1. 1 April 2001 - 30 September 2001.
Project Progress Report 2. 1 October 2001 - 31 January 2002.
Project Progress Report 1. 1 April 2002 - 30 September 2002.
Project Progress Report 1. 1 October 2002 - 31 December 2002.

Annual Reports
Annual Report 2000
Annual Report 2001
Annual Report 2002

PRA Reports
Oruko, L & Ndun'gu, B. CABI/KARI/HRI/NRI/University of Reading/IACR Rothamstead collaborative project Final Socio-Economic Report for the Peri-Urban Vegetable IPM Thematic Cluster, January 2001.

Wachira, S. Rural rapid appraisal on kale seed selection/in choice Kinale Division, Limuru District, April 2001.

Njuki, J. Farmer perceptions of virus diseases of vegetables in Ruiru and Athi River., September 2002.

Factsheets (see Appendix 9)
Hughes, SL, Phiri, NA, Chacha, C, Kuria, A Mwaniki, A, Achieng, B. Ndirangu, S, Simons, S, Kibata G & Spence, NJ. Potential of self selection of seed of tolerant/resistant components of land races of kale for disease management in Kinale.

Hughes, SL, Phiri, NA, Chacha, C, Kuria, A Mwaniki, A, Achieng, B. Ndirangu, S, Simons, S, Kibata G & Spence, NJ. On-farm epidemiology and management of virus disease of *Brassica* crops.

Research Highlights
Hughes, SL, Phiri, NA, Chacha, C, Kuria, A Mwaniki, A, Achieng, B. Ndirangu, S, Simons, S, Kibata G & Spence, NJ (2001). Management of virus diseases of important vegetable crops. Annual report.

Posters (see Appendix 9)
Spence, NJ, Hughes, SL, Nywandam, L, Briddon, RW, Bull, SE, Bedford I & Kibata, G An emerging Begomovirus problem in tomato crops in Kenya. Abstracts of the 3rd International Gemini Symposium, 24-27 July 2001. [Science, academic poster]

Hughes, SL, Phiri, NA, Chacha, C, Kuria, A Mwaniki, A, Achieng, B. Ndirangu, S, Simons, S, Kibata G & Spence, NJ. Characterisation of viruses that infect vegetables in Kenya. AAB conference, Advances in Plant Virology 17-19 April 2002, Homerton College, University of Cambridge. [Science, academic poster]

Hughes, SL, Phiri, NA, Chacha, C, Kuria, A Mwaniki, A, Achieng, B. Ndirangu, S, Simons, S, Kibata G & Spence, NJ. Towards managing virus infection of field vegetables in Kenya. BSPP Presidential Meeting, Plant Pathology & Global Food Security 8-10 July 2002, Imperial College, University of London. [Science, academic poster]

Anticipated publications in peer reviewed journals
Activity 1
- Identification of *Beet mosaic virus* in swiss chard in Kenya
- Characterisation of virus samples in peri-urban regions of Nairobi, Kenya
- The economic significance of viruses of *Brassica* crops and the effect of timing of virus infection

Activity 2
- Methods of protecting *Brassica* seedbeds from virus infection and their effect on reducing virus infection.

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Spence, NJ (1999). Survey of viruses of vegetable crops in the peri-urban production system of Kenya. Final Technical Report for DFID CPP Project ZA0272.

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Appendix 9

Disseminations

On-farm epidemiology and management of virus diseases of *Brassica* crops (Factsheet)

Potential of self selection of seed of tolerant/resistant components of land races of kale for disease management in Kinale (Factsheet)

POSTERS:

An emerging begomovirus problem in tomato crops in Kenya

Characterisation of viruses that infect vegetables in Kenya

Towards managing virus infection of field vegetables in Kenya