CROP PROTECTION PROGRAMME

Pest management in horticultural crops; an integrated approach to vegetable pest management with the aim of reducing reliance on pesticides in Kenya

R7403 (ZA0300)

FINAL TECHNICAL REPORT

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Abbreviations

AVRDC – Asian Vegetable Research and Development Centre
CABI – Centre for Applied Biosciences
CABI-ARC – Centre for Applied Biosciences – Africa Regional Centre
CPP – Crop Protection Programme
DBM – Diamondback Moth
DFID – Department for International Development
EU – European Union
FFS – Farmer Field Schools
FSS – Farmer Seed Selection
HMB - Habitat Management Based (IPM approach)
IPM – Integrated Pest Management
Kabete – Kabete Farm of the University of Nairobi
KARI – Kenya Agricultural Research Institute
KEPHIS – Kenya Plant Health Inspectorate Service
KIOF – Kenya Institute of Organic Farming
LOK – Lever-operated knapsack
NARL – National Agricultural Research Laboratories
NHRC – National Horticultural Research Centre
NRI – Natural Resources Institute
PxGV – *Plutella xylostella* Granulosis Virus
SUP – Safe Use Project (of pesticides)
UoN – University of Nairobi

Executive Summary

Vegetable production constitutes a key component of the livelihood strategy of small-scale, peri-urban farmers in Kenya. The production system is constrained by the negative impact of pests (low yield/quality of crops) and drawbacks or hazards resulting from excessive or inappropriate use of pesticides. In 1996, the Crop Protection Programme of DFID commissioned a number of complementary research projects to address these constraints. This report describes the outputs of the second phase of the central project, ‘Pest management in horticultural crops; an integrated approach to vegetable pest management with the aim of reducing reliance on pesticides in Kenya’ (R7403; ZA0300)

During the first phase (1996-1999), key pest constraints affecting peri-urban vegetables were identified through extensive on-farm surveys. A diversity of natural enemies was observed, particularly on organic farms, but abundance was shown to vary according to pesticide regime. A parallel survey of pesticide use by farmers also revealed that application methods were often imprecise and occasionally unsafe. Research activities focussed on identification of selective pesticides and improving the efficiency of pesticide application, including development of a modified spray lance, the V lance.

In the current phase (1999-2002), the overall aim was to develop and integrate promising chemical, cultural, genetic and biological control options into an IPM strategy. In terms of developing safer, more effective pesticide-based strategies (Output 1), the efficacy, acceptability and demand for the V lance have been clearly demonstrated, and a campaign to raise awareness of the technology is currently underway. Efficiency of pesticide application has been further researched by evaluating adjuvants to improve retention and spread of pesticides. Natural enemy enhancement (Output 2) has been achieved on-farm through the use of benign pest control methods including intercropping, refugia and the use of organic manure. Use of selective, conventional and non-conventional pesticides for the key pests, DBM and aphids, were also shown to conserve natural enemies. No pesticides are currently effective against both pests, and even handpicking, which may be practical on small areas, was only effective against aphids. Procedures for estimating the effect of natural enemies were established and field experiments were undertaken to quantify their impact on key pests. A search for entomopathogens of aphids yielded >100 fungal isolates, two of which have potential as biocontrol agents. Improved planting material (Output 3) was demonstrated by farmer seed selection (FSS) trials. The farm-selected variety performed better than commercially available kale seed, so this could be a way of improving yield/quality while reducing purchase costs. In contrast, new tomato germplasm from AVRDC did not perform as well as currently available commercial varieties in Kenya, and was blight-susceptible (however, new lines developed by AVRDC which are said to be blight-tolerant, will be available to the project from March 2002 for assessment). Knowledge transfer to small-holder farmers (Output 4) was achieved using existing uptake pathways e.g. farmer-managed trials, workshops and field-days, and new uptake pathways were identified through strategic partnerships with industry e.g. agrochemical companies and vegetable exporters. Promotion was aided by the production of a range of high profile, farmer-friendly dissemination materials including newspaper and magazine articles, posters and calendars (the latter in Swahili and English).

The project has developed the 'Habitat Management Based (HMB) approach’ to popularise and promote a practical pro-poor IPM strategy for small-scale, peri-urban vegetable farmers. This 3-tier strategy is based on enhancement of natural regulatory mechanisms, biologically-based interventions, with target-specific chemical interventions being used as a last resort. The HMB strategy now needs to be demonstrated and validated on-farm, compared with existing farmer practices, and widely promoted. These are the key aims of the third phase of the project which has been submitted to the CPP.

Background

Smallholder vegetable farming is an important engine for economic development in peri-urban and peri-rural areas of eastern and southern Africa. Increased productivity of vegetables is, however, constrained by the impact of pests and diseases. Farmers currently rely heavily on spraying pesticides to reduce the damaging effects of pests and diseases on yield and quality of vegetables, but pay little attention to alternative tactics such as harnessing the control potential of natural enemies. During the first phase of the peri-urban vegetable IPM project (April 1996 to March 1999), it emerged that four main crops (kale, cabbage, tomato and spinach) accounted for over 95% of peri-urban vegetable production. The most important pests were found to be DBM and aphids whilst the most important diseases were found to be early blight, late blight, virus and *Cercospora* leaf spot. These crops and their pests and diseases became the major focus of subsequent research activities. On brassicas, extensive surveys of natural enemies, particularly of the major brassica pests (DBM and aphids) have revealed a rich diversity of natural enemies. The survey work identified the need for selective or less disruptive techniques, which were more benign to predators and parasitoids.

The overall aim of the second phase of the project was to develop and integrate improved methods for the control of key pests and diseases of vegetables in peri-urban areas in Kenya. Major objectives of the project were: the development of safer, more effective pesticide-based strategies, including an increased understanding of the effects of pesticides on natural enemies; enhancement of the role of natural enemies in natural biological control of major pests; and improvement of planting material (including methods by farmers themselves), in order to develop an integrated strategy which reduces the current reliance on pesticides for the successful management of vegetable pests.

Adoption of this approach would empower farmers with sustainable and effective techniques for managing pests and diseases. This, in turn, would reduce the hazards resulting from excessive or inappropriate use of pesticides, which would otherwise further degrade human health and natural resources. Yield, quality and seasonal availability of vegetables would be improved.

The project was a collaborative research initiative involving farmers, extensionists and specialists such as entomologists, plant pathologists, pesticide application specialists, nematologists, socio-economists and biometricians from KARI, CABI-ARC and NRI.

Project Purpose

The Purpose of the Peri-urban Production System at project inception was 'to improve the volume, quality and seasonal availability of food and crop products through the reduction of physical and economic losses caused by pests'. This has recently been revised to 'promotion of pro-poor strategies to reduce impact of key pests, improve yield and quality of crops, and reduce pesticide hazards in peri-urban systems'. The production system is characterised by intensive land use, often high and excessive use of pesticides, and typically produces high value crops such as vegetables.

This project was one of a number commissioned by the CPP to target output 1 of the Production System. Pest and disease incidence has been identified as the primary production constraint within the smallholder business environment. In this context, the need to manage pests more effectively through enhancement of natural regulatory systems, and safer and more judicious use of pesticides, must be inherent in any project implemented to contribute to the production system Purpose.

Research Activities

Output 1. Safer, more effective pesticide-based strategies developed for management of pests and diseases in small-holder vegetable systems.

Activity 1.1 Optimise efficiency of pesticide application by farmers using existing technologies (lances and nozzles)

On-farm observations of pesticide applications made by small-holder vegetable farmers showed that the quality of applications was often poor and/or ineffective. There were a number of different reasons for this: an unsuitable products were used, spray was not deposited evenly on the crop, standard sprayer nozzles were too coarse resulting in unnecessarily high volume application rates and coarse droplet spectra, and calibration was frequently not carried out accurately.

A series of on-station trials showed that improved technology and methods could produce much better results using simple and relatively inexpensive modifications to current equipment and practices. Two such modifications were developed and tested in trials:

- the V lance, which allows spray to be directed upwards, giving an improved spray distribution, particularly on the lower leaf surfaces (see Figures 1 and 2 below).
- finer spray nozzles which atomise the spray more effectively and allow lower and more appropriate volume applications to be made.

The next stage was for smallholder vegetable growers to assess the performance of V lance technology on their farms (Koech & Karanja, 2000). 11 smallholder farmers in Nyathuna (8) and Athi River (3) were supplied with swivel kits to convert a conventional lance into a V lance, and each lance was fitted with the correct adapter for the thread type found on their existing spray lances.

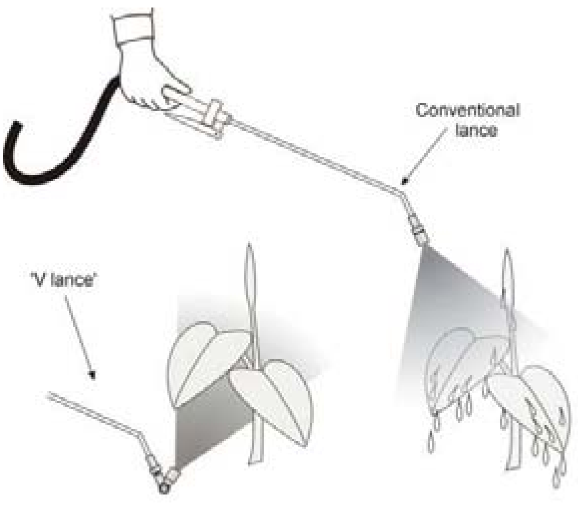


Figure 1: Underleaf delivery of spray by a V lance and 'top-down' application from a conventional lance

Figure 2: The V lance which consists of a swivel (black) and thread adapter (white) on the end of a spray lance.

Results

a) V lance

The V lance, was shown to give improved spray coverage on the crop compared with a conventional lance (Fig. 3). The amount of pesticide deposited on under leaf surfaces is much higher when applied using a V lance compared with a conventional lance. The amount of pesticide deposited on the top of the leaves was similar using either lance. Since the underleaf surface is where many pests are found, and where some diseases achieve initial tissue infection, this improved underleaf deposition is likely to result in a better crop.

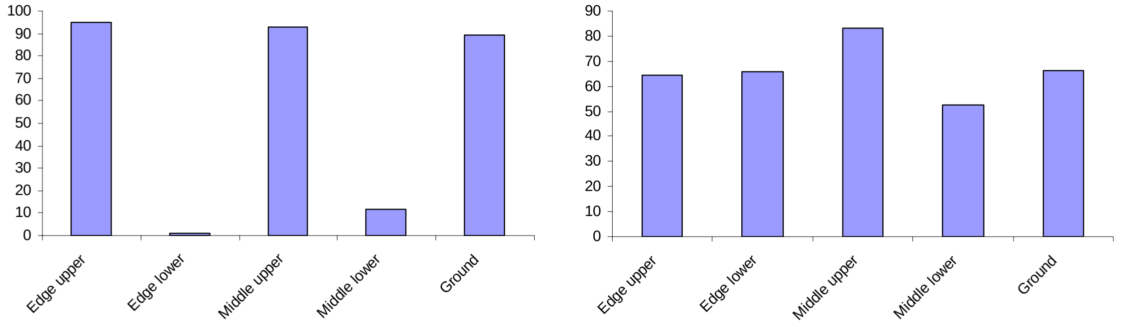


Figure 3: Comparison of spray distribution on kale (percentage area cover) using a conventional lance (left) and a V lance (right)

Field trials were established at NARL, Nairobi on 2000 to quantify the benefits of using a V lance in comparison to a conventional lance for the application of two different pesticides on two different crops i.e. propargite (Omite) and lambdacyhalothrin (Karate) against pests on tomato and kale respectively. For the experiment using Omite on tomatoes, three treatments i.e. Omite applied using a V lance, Omite applied using a conventional lance and a control treatment were compared using a randomised block design (5 replicates) over an entire growing season. Omite applied using a V-lance resulted in significantly lower numbers of mites per plant than Omite applied using a conventional lance ($P<0.001$) (Fig. 4). However, the treatments did not have a signficant effect on yield.

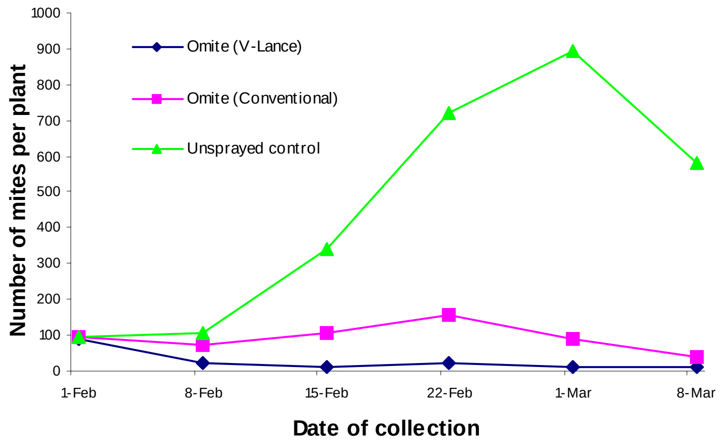


Figure 4: Effect of Omite applied using either a V lance or a conventional lance on populations of mites on tomato plants.

For the experiment using lamdacyhalothrin on kale, five treatments i.e. full dose or half dose each applied using either a V lance or a conventional lance, together with a control treatment were compared using a randomised block design (3 replicates). Although V lance led to fewer aphid populations and higher yields compared to other treatments, these differences were not significant statistically.

The benefits of using the V lance were popularised using cartoons. Figure 5 shows how the pesticide can be directed upwards using V lance technology, so that it reaches pests sheltering under leaves.

Spraying from below kills pests which hide under leaves
Unyunyuziaji wa viuavisumbufu kwa chini huua visimbufu vinavyojificha chini ya majani

Figure 5: A cartoon showing the V lance in action, which appears as one of a series of cartoons in a calendar produced by the project.

Farmers' reactions to the V lance were favourable and they appreciated the value of upwardly directed spray and its resulting improved underleaf coverage. After three months of participatory research the pilot farmers' views on the V lance ranged from 'no difference' (between V lance and conventional lance) to improved pest and disease control, and pesticide efficiency – in other words how much pesticide was required to achieve the same effect (Fig. 6).

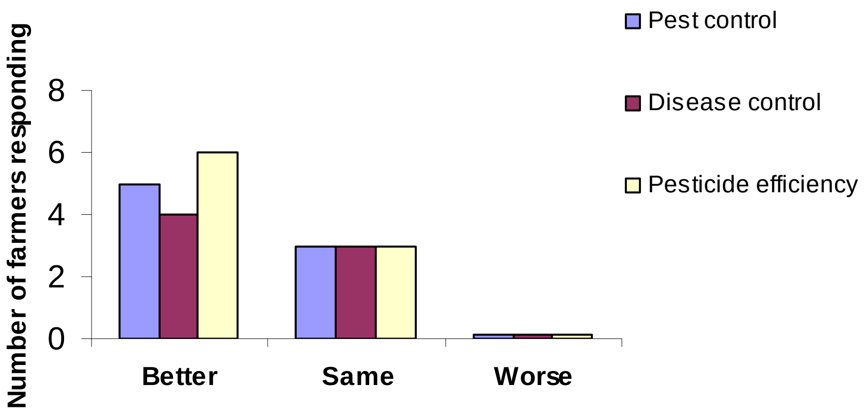


Figure 6: Views of farmers in Athi River and Nyathuna areas of Kenya on the efficacy of the V lance compared to the conventional lance.

Several farmers reported that the V lance was not suited to cabbage spraying because the target crop was too short and DBM are often found in the central growing point. However, they reported that it was advantageous for taller crops such as kale and tomato. Some farmers had found other creative uses for the V lance – in one instance, more effective under-body spraying of cattle for tick control.

Making V lances available to farmers

Currently the equipment to convert conventional lances to V lances is not available to farmers in Kenya. Throughout the project, discussions were held with the local agency of the largest local sprayer manufacturer and retailer (Hardi, Kenya) about how they could be made available for farmers to purchase. Essentially this will hinge on stimulating sufficient local demand to justify supplying a compatible swivel with new sprayers, or stocking them for sale as upgrades. In order to stimulate interest by commercial outgrowers, a set of swivel adapters were supplied to a commercial company with links to large scale horticultural production (Dudutech) in September 2001 for use and assessment by their smallholder outgrowers. To date, Dudutech has not given any feedback, but it is hoped that these and other companies will become interested enough to recommend V lances for use on their farms. Hardi, Kenya has agreed to pilot the V lance adapter kits through their retail outlets and their network of field staff who currently demonstrate and promote their sprayers. The provision of small initial quantities of the kits is the subject of a proposal currently under development.

b) Finer nozzles

The use of finer nozzles (smaller diameter orifices), resulting in lower spray volume application rates and smaller droplets, has been shown to increase the speed and effectiveness of sprays applied using the standard lever-operated knapsack (LOK) sprayers used by smallholder farmers in Kenya. Surveys carried out by the project revealed that volumes applied ranged from 200 to 1500 litres per hectare. Anything over 400 to 500 litres per hectare is wasteful for most vegetable crops. The simplest and most effective way to reduce the volume applied is to fit a nozzle which produces both a lower flow rate and a finer spray spectrum. A nozzle can be assessed roughly by a visual examination of the spray, and by measuring the flow rate at normal pumping pressure (around 2-3 Bar). A flow rate above 0.75 litres per minute can be regarded as too high and likely to produce sprays which are too coarse. Surveys of shops supplying inputs, including sprayers, to farmers around Nairobi, showed that in only two of the eight shops visited, were replacement nozzles available, and only one had a range of suitable nozzles with appropriate flow rates. Suppliers indicated a willingness to supply alternative, finer nozzles, provided there was a market. Currently the market is logjammed with no availability to stimulate demand and therefore no demand to stimulate availability. Awareness-raising of the benefits of finer nozzles, together with appropriate training were considered to be the seedcorn investments required to free the logjam.

c) Correct pesticide choice and dosage

An interesting finding was that in many cases farmers were not using the correct dose rate, or applying an appropriate product. For example, lamdacyhalothrin was used in an attempt to control red spider mites, whereas it is not recommended for this pest, and has very limited acaricidal activity. Another product (mancozeb) was used at a fraction of the recommended dose rate. These findings showed up the weakness of some types of application carried out by farmers and demonstrated that there is a need for better information and training in spray application.

d) Influencing industry

A series of discussions were held with the pesticide company Rhone Poulenc (now Syngenta), on improving the accuracy of dosage applied by smallholder farmers. These discussions aided the development of a soluble tablet formulation of pesticide. These tablets contain sufficient active ingredient for a single sprayer tankful, and are safe and easy to use – an attempt by industry to make calibration safe and easy. Initially the company (Rhone Poulenc) were planning for the tablets (‘Decis Tab’) to contain a dose which assumed a volume application rate of 200 litres per hectare. However, project research had indicated that at least 400 litres are generally applied. After attending one of the project workshops and seeing the relevant project report, Mr Michael Strano, Horticultural Products Manager, Rhone Poulenc, reduced the dose in the tablets accordingly. Had they not done so, the dosage (of active ingredient) used by farmers would have been more than double the recommended dose.

Conclusions

- Efficacy, acceptability and demand have been demonstrated for both the V lance and finer nozzles (i.e. the swivel kit). The potential advantage for farmers is equal or improved efficacy at half of the recommended dose – a cost-saving which farmers report to be an attractive benefit. A campaign is now underway to raise awareness further, to increase the market demand and to make the technologies available locally at prices acceptable to smallholder farmers.

- Field trials demonstrated that, lamdacyhalothrin applied at half the recommended dose with the V lance has equal efficacy against aphids compared to the full dose applied with a conventional lance.

- Training and information resources are ongoing requirements for smallholder farmers to enable them to apply pesticides more safely and efficiently. The project has identified the major areas of concern; product choice, volume and dosage, droplet size and operator safety and is engaged in dissemination of messages through various media (see later) to address these issues.

- The project has had a significant influence on the development of a new product formulation, resulting in significant benefits to smallholder vegetable farmers. As a result of project outputs, the product Decis Tab was produced with half of the active ingredient content originally planned resulting in lower cost and a reduction in the pesticide risk.

Activity 1.2 Assess the effectiveness of new application technologies, including formulation additives

Brassicas are difficult to wet with pesticide sprays because the leaf surfaces are waxy. This results in three major problems:

- wastage of pesticide as it rolls off the leaves
- low retention of pesticide deposits on the leaves where it is needed.
- pesticide is retained in discrete droplets which dry to form small points of concentrated product, surrounded by large areas with no deposit. Some of the bio-efficacy of such foliar pesticides comes from direct contact action as the pesticide falls on the pest, but due to the unavoidable macro-variability of deposits, effective results also depend on subsequent secondary contact with deposited pesticide as the insects move around the leaf surfaces. The more the insecticide spreads on the leaf surface, the greater the likelihood of this secondary contact occurring.

Retention and spreading can be improved by the use of additives – known as adjuvants – which reduce surface tension of the spray liquid. There are many commercial adjuvants on the world market, but the number available in Kenya is small, and the cost is perceived to be high by smallholder farmers. In this activity, spray distribution on brassicas was examined when using different adjuvants. A standard pesticide formulation with no additives was compared with ones in which either a low-cost wetting agent – domestic detergent - or a commercially available adjuvant (Designer) had been added. Fluorescent dye was added to each formulation so that deposits could be detected and compared under UV light.

One trial was carried out in October 1999, but the standard fluorescent dye used produced deposits which were difficult to quantify. Subsequent work in the UK identified a dye (Uvitex OB) with better image contrast against the background of a brassica leaf. The trial was repeated twice more in March 2000 on kale plants. Analysis of the dried leaf samples is being carried out in the image analysis suite at NRI using a Quantimet 520 machine. This analysis was delayed for over a year due to the need to upgrade the image analyser with a 'grey-store' in order to cope with this new type of analysis (still images rather than direct input from a video camera). In this technique, still images of the UV-illuminated leaves are produced using a digital camera with high sensitivity to the fluorescent emitted wavelength. Then the tone and colour contrast is optimised using graphics editing software, before the images are converted to a format for import into the image analyser, which is used to determine percentage area cover of the spray deposits.

Results

Figure 7 shows an image of one of the leaves and Figure 8 shows a bar chart of the results.

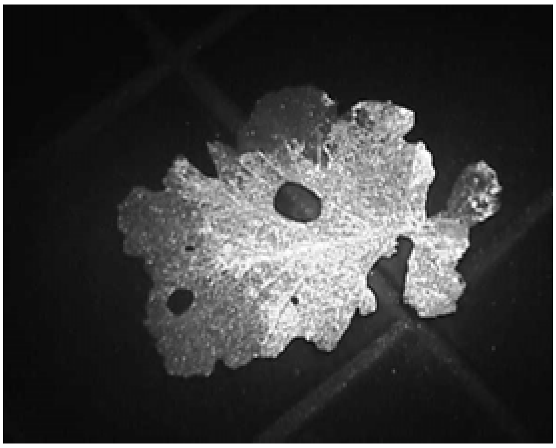


Figure 7: Kale leaf with fluorescent deposits under UV illumination

Bar chart to be inserted when data analysis finalised

Figure 8: Percentage area cover of the spray on kale leaves with two adjuvants

Conclusions

- The spray coverage analysis technique developed to assess deposits of spray on leaves works well and could be used as a standard method to assess the effect of other adjuvants and/or spray application enhancements. This new technique for analysing imported images, will allow files to be created in any country, and subsequently analysed in another country using the image analyser.

- Visual impressions indicate that the additive 'Designer' and locally purchased detergent both gave better retention and spread than the standard formulation. If this is borne out by the data from the image analyser, domestic detergent (added at a rate of 13 ml/10 litres) could be recommended as an adjuvant for spraying brassicas. The analysis is incomplete at the time of writing this report, so it remains to be seen whether analysis confirms that the detergent performs as well as the commercial adjuvant. Certainly the cost of the detergent is more affordable. 'Designer' costs £2 to £3 per ha and detergent costs £0.2 per ha. Any potential benefits of this technology when applying synthetic pesticides are expected to extend to the application of biological and botanical products.

Activity 1.3 Identify and refine methods of applying non-conventional pesticides

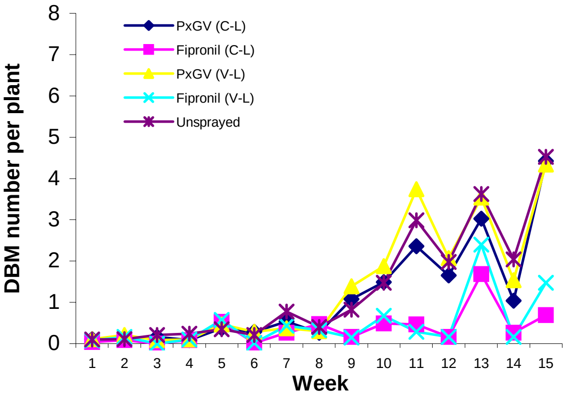
A key factor in determining the efficacy of non-conventional pesticides e.g. biopesticides is the efficiency of spray application. As biopesticides are a relatively new technology, little research has been carried out into methods of improving the efficiency of application. Previous work has shown that the entomopathogenic virus, *Plutella xylostella* Granulovirus (PxGV) applied using a conventional lance has enormous potential as a non-conventional pesticide (refer Biorational Brassica IPM in Kenya – R7449; ZA0319). However, further work was required in order to determine whether the efficacy of the entomopathogen could be improved using modified V lance technology. Trials were established to see if applying PxGV using the V lance leads to better control of DBM as compared with a conventional lance. The efficacy of PxGV was compared with that of a chemical pesticide, fipronil (Regent) (which had been shown in previous trials to give good control of DBM) applied using conventional and V lance technology, together with an untreated control. The experiment was established in a randomised block design (4 replicates) at two contrasting sites (NHRC, Thika and NARL, Nairobi) over two growing seasons i.e. long rains 2001 and short rains 2001.

Data were recorded at weekly intervals, just prior to treatment application, as follows:

Weekly counts and scores of insect pests and their associated natural enemies on 10 plants per plot selected randomly each week from within the plot.

Results

DBM numbers during both growing seasons were generally low, and the modified V lance technology was shown to have no effect on either the efficacy of PxGV ($p=0.914$) or fipronil ($p=0.74$) in controlling DBM. Fipronil was the most effective product ($p<0.001$), and, on average, there were found to be significantly fewer DBM on PxGV-treated plants than the control ($p<0.001$).



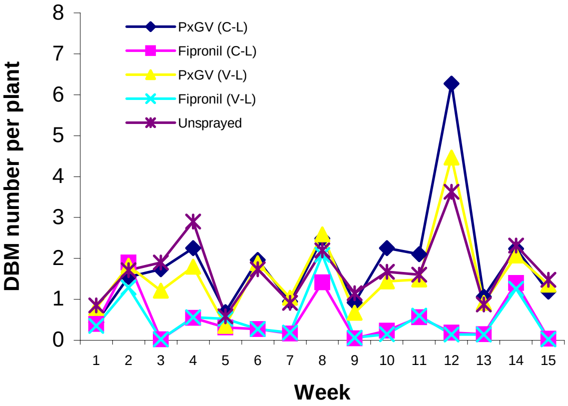
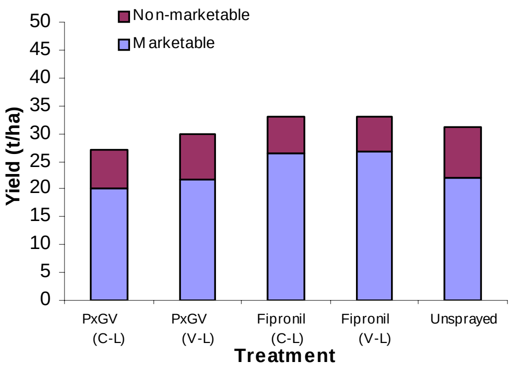


Figure 9: Effect of PxGV and fipronil applied using either a V lance or conventional lance on the population of DBM at (left) NHRC, Thika and (right) NARL, Nairobi

Marketable yields were higher at NARL than at NHRC ($p<0.001$), but at both sites, fipronil led to higher yields (42t/ha) than the other treatments (32-34t/ha) ($p<0.001$). The type of lance did not influence the final yield of kale ($p=0.961$ for fipronil, $p=0.892$ for PxGV).



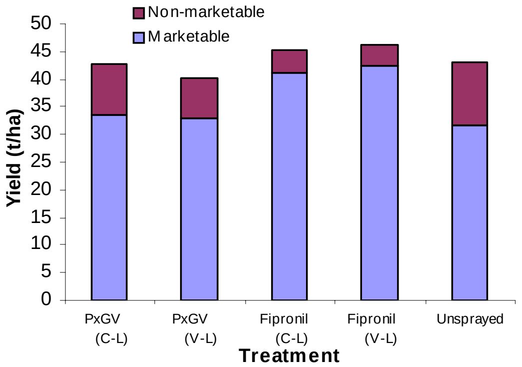


Figure 10: Effect of pesticide application method and pesticide on the yield of kale (marketable and non-marketable) at (left) NHRC, Thika and (right) NARL, Nairobi.

Conclusions

There was little difference observed between the performance of the two lances. Lack of a difference in the effect of pesticide application lances could be attributed to the use of fipronil doses that were too high, and therefore non-discriminatory.

Output 2. Natural enemy impact maintained or enhanced for control of major pests

Activity 2.1 Quantify the impact of selective pesticides particularly aphicides on pests and natural enemy populations

Most pesticides in common use are relatively broad spectrum and affect natural enemies to a greater or lesser extent. However, there are some newer pesticides (and one or two older ones) which exhibit some degree of specificity and these could potentially be used in a spraying regime which is more complementary to the activities of natural enemies of the most important pests.

Dialogue was established with agrochemical manufacturers and retailers, and the literature reviewed in order to identify promising selective product options (both locally available and imported) for control of the two most important vegetable pests, DBM and aphids. Five products were chosen including a relatively new product, pymetrozine, which kills aphids by disrupting their feeding. Other products tested were chlorfenapyr, pirimicarb, lambdacyhalothrin and fipronil. Table 1 gives names and some other basic data on the pesticides, including cost per hectare per week of treatment at recommended rates. Five separate on-station field trials were carried out at two contrasting sites (NHRC, Thika and NARL, Nairobi) and over three growing seasons (short rains in 1999 and long and short rains in 2000) to test the efficacy of the products on kale pests, and their impact on beneficial arthropods, when compared with an untreated control. Trial design in all cases was a randomised block with four replicates. Weekly pest/disease/natural enemy counts were carried out on 10 randomly chosen plants per plot per treatment, together with appropriately timed yield assessments (divided into marketable and unmarketable) from sequential harvesting of leaves.

Table 1: Products, active ingredients, mammalian toxicity and cost of products tested (£1:KSH110/-)

Trade name	*Active ingredient*	*Dose (g a.i./ha)*	*Spray interval (weeks)*	*Mammalian toxicity of formulation(mg/kg rodent)*	*Cost per ha per week KSh*
Pirimor	pirimicarb	250	2	200	375
Secure	chlorfenapyr	108	4	1225	2502
Karate	lambdacyhalothrin	17.5	2	2857	781.5
Chess	pymetrozine	200	2	11640	*
Regent	fipronil	25	3	1900	316
Unsprayed					0

* Not available in Kenya at time of writing

Results

Figure 11 shows that lambdacyhalothrin, together with pirimicarb, were the most effective aphid control products (p = <0.001). Pymetrozine was the next best product but is only partially effective in practice. Chlorfenapyr and fipronil were the most effective products for DBM control (Fig. 12) resulting in significantly lower numbers of DBM per plant than all other treatments (p<0.001, all). Lambdacyhalothrin resulted in consistently higher DBM numbers than all other treatments (p<0.001, all), and, in a similar reversal of performance, the most effective DBM products, chlorfenapyr and fipronil, gave very poor aphid control. Parasitism levels were low (< 9%), possibly due to the generally low numbers of aphids and DBM, which did not allow the build-up of parasitoids. No significant differences between treatments were observed (p=0.475).

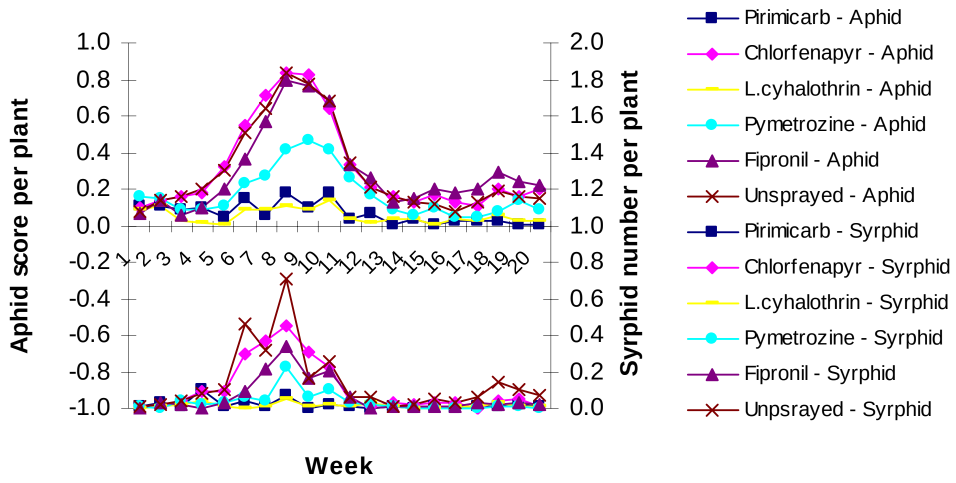


Figure 11: Interaction between aphid and syrphid (important aphid predators) populations

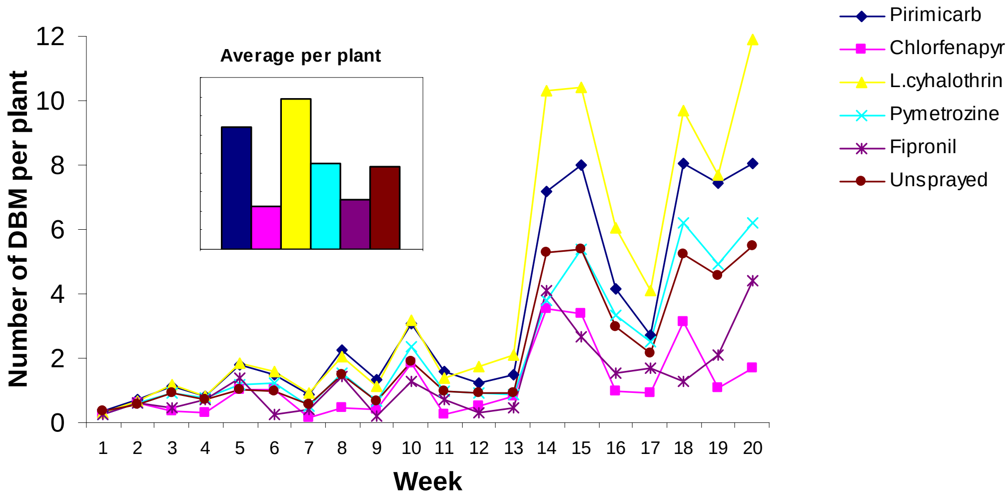


Figure 12: Effect of pesticides on DBM populations (average for season – see insert)

Fig. 11 also shows an interesting interaction between aphid and syrphid populations. Syrphids are known to be very important predators of aphids and their numbers in plots where aphid control was poor, appeared to track those of aphids quite closely. It is difficult to unpick the other processes fully in this trial since there are two possible reasons for consistently lower syrphid numbers in the lambdacyhalothrin and pirimicarb treatments than in other treatments ($p<0.05$, for the majority of observations). Either the pesticides in question were killing the syrphids directly, or the lack of a food source meant that their numbers could never build up. Chlorfenapyr and fipronil had the least effect on syrphid numbers – as well as retaining an aphid food source (it gives poor aphid control). It is also possible that they were not be killing the syrphids which built up on this food source, although syrphid numbers on both the chlorfenapyr and fipronil plots were significantly lower than on the unsprayed control plots ($p=0.004$).

Unsprayed plots produced significantly lower marketable yields ($p<0.001$, compared to all other treatments) than the sprayed treatments (consistently across all 5 trials) (Fig. 13). Sprayed treatments produced similar amounts of marketable and non-marketable produce.

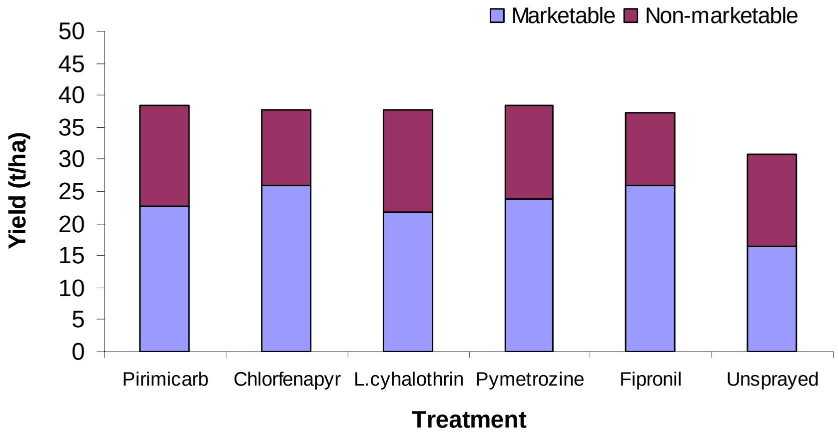


Figure 13: Effect of pesticides on marketable and non-marketable yield of kale

Conclusions

- Lambdacyhalothrin and primicarb were the most effective products against aphids and are significantly more effective than no control ($p = <0.001$)
- Chlorfenapyr and fipronil were the most effective products against DBM and are significantly more effective than no control ($p<0.001$)
- No products have an acceptable level of effect on both DBM and aphids.
- It seems there is not an effective all-purpose product and that two of the tested products are required in brassicas when DBM and aphid numbers rise to high levels
- Yield in these trials was best when using chlorfenapyr and fipronil, indicating that preventing DBM damage was the most important method of increasing yield.
- DBM numbers in the unsprayed control treatment (and in all other treatments) stayed low for several weeks – scouting and spraying at a threshold would be a more efficient strategy than calendar spraying.
- Chlorfenapyr and fipronil had a significant effect on syrphids compared with the unsprayed control treatment ($p =0.004$).
- Conclusions on the impact of pirimicarb and lambdacyhalothrin on syrphids cannot be drawn from the data due to their effective reduction of the primary food source for syrphids, namely aphids. Laboratory trials are now required to determine whether lambdacyhalothrin or pirimicarb are toxic to syrphids.

Table 2: Summary of field performance of selective pesticides

Product	*DBM control*	*Aphid control*	*Impact on DBM parasitoids*	*Impact on aphid parasitoids*	*Impact on syrphids*
Pirimicarb	red	green	green	green	red
Chlorfenapyr	green	red	amber	amber	green
Lambdacyhalothrin	red	green	amber	green	red
Pymetrozine	red	amber	amber	green	amber
Fipronil	green	red	amber	green	red

green = good (high efficacy against pests and minimal impact on natural enemies)
amber = moderate (moderate efficacy against pests and moderate impact on natural enemies)
red = bad (low efficacy against pests and high impact on natural enemies)

Activity 2.2 Investigate whether more benign technologies can conserve and enhance natural enemy population.

An on-farm study was undertaken in order to investigate whether more benign technologies could conserve or even enhance natural enemies of insect pests. In the same agro-ecological zone (Kiambu District, Kenya), ten farms which employed conventional pest control practices (typical) were compared with ten farms where benign pest control methods were practised (benign). Conventional practices included routine application of inorganic pesticides, monocropping and heavy use of inorganic fertilisers, whereas benign practices included intercropping, refugia, mulching, use of organic manure and use of botanical pesticides. Most of the farmers employing benign technologies had, at some stage, been trained by the Kenya Institute of Organic Farming (KIOF). The crops grown were mainly kale, cabbage and spinach although other crops including coriander, lettuce, leek and tomatoes were also grown. Crops on each of the twenty farms were sampled just before harvest (twenty sample plants per crop per farm). Data collected included pests and their natural enemies, together with information on the type of pest control products/technologies used by the farmer.

Further field trials were undertaken in order to quantify the impact of natural enemies in reducing the numbers of the two main insect pests, DBM and aphids. In the first trials, a total of 30 unsexed DBM moths were each released into cages containing kale plants for 24 hours and allowed to lay eggs on the plants. The eggs were either protected from, or exposed to, predators and parasitoids. This was done by applying insect glue (tangle-foot) at the stem bases of plants to prevent predators such as ants from crawling up the stem, and/or by covering plants with cages with fine mesh to exclude airborne predators and parasitoids. Other plants were left as untreated (cages removed, no tangle foot). The trial was repeated at least four times at each of two sites (Kabete and NHRC, Thika). The fate of the eggs was assessed after 2 days.

In the second trial, the effect of different treatments on the impact of natural enemies on DBM and aphids was assessed in a season long experiment at two sites (Kabete and NHRC, Thika). Plots of kale plants were treated with either insect glue (to exclude crawling predators), sprayed with lambdacyhalothrin (to exclude insects, except DBM), treated with insect glue and sprayed with lambdacyhalothrin (to exclude both crawling and flying insects except DBM), or left untreated. Treatments were arranged in a randomised block design with 3 replicates. The populations of DBM and aphids were assessed every week to determine the effects of the treatments.

Results

Use of ‘benign practices’ resulted in a significant increase (p<0.001) in the abundance of natural enemies (Figure 14). Interestingly, the ranking of the most important pests and natural enemies on each crop was consistent, irrespective of whether ‘typical’ or ‘benign’ practices were employed, but there was a large variation in absolute numbers of the natural enemies.

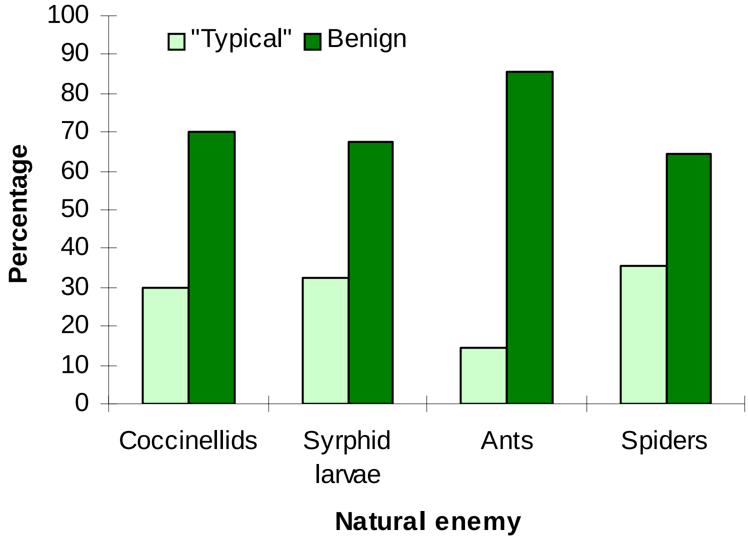


Figure 14: Effect of benign practices on natural enemy populations

In the first trials, average loss of eggs ranged from 16 – 48%. Percentage of eggs predated was significantly higher (P=0.05) on plants where crawling and flying natural enemies had free access (Fig. 15).

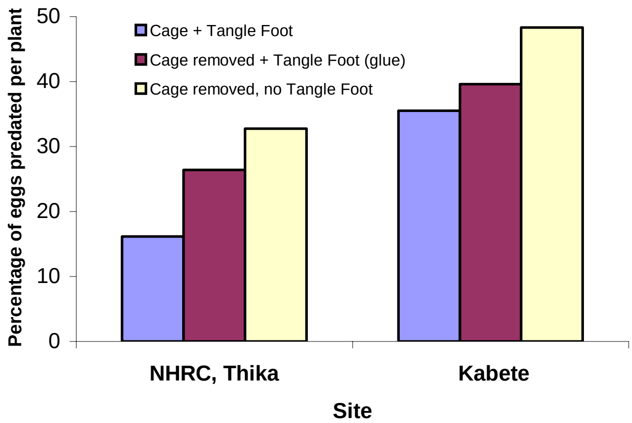


Figure 15: Predation of DBM eggs on kale after 2 days exposure in the field at NHRC, Thika and Kabete.

In the second trials, DBM populations remained low and only started to increase from weeks 14 and 10 at Kabete and NHRC, Thika, respectively (Fig. 16). No consistent effects of treatments on DBM populations were observed.

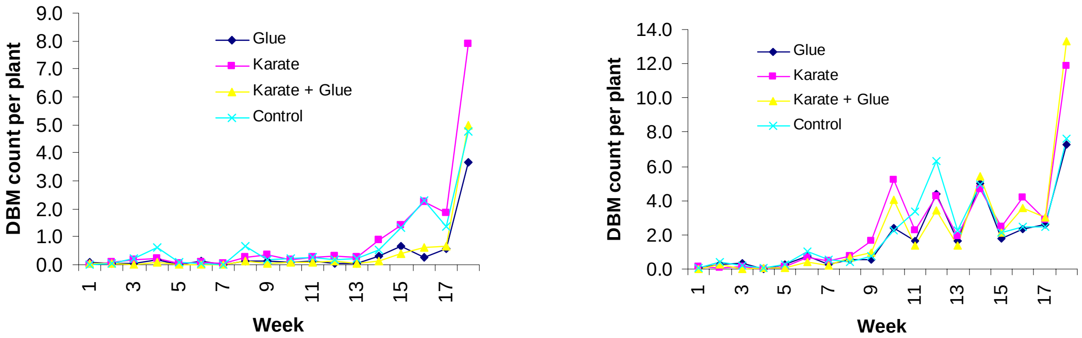


Figure 16: Population of DBM on kale plants exposed to different treatments to exclude or include natural enemies at Kabete (left) and NHRC, Thika (right).

Aphid populations at both sites rose to a peak on about week 8 (Fig. 17). Untreated controls generally supported the highest populations of aphids. Lambdacyhalothrin killed aphids, leading to low pest populations, especially at NHRC, Thika. Excluding crawling predators from accessing aphids on the plants led to a high pest population at NHRC, Thika, but this effect was not repeated at Kabete.

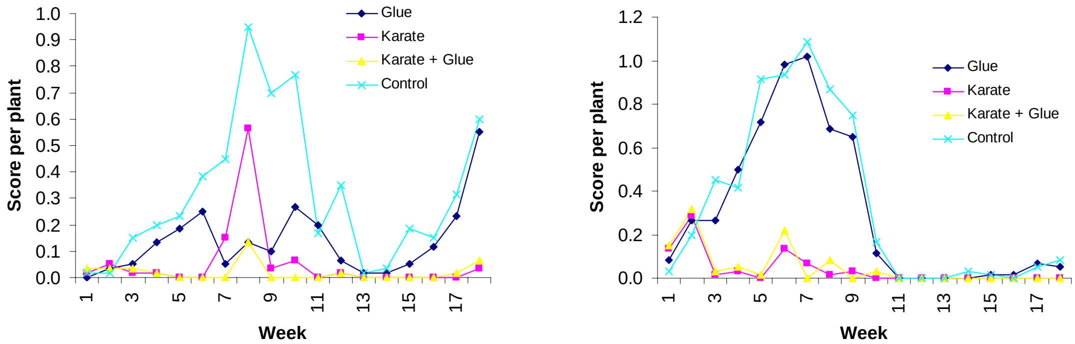


Figure 17: Population of aphids on kale plants exposed to different treatments to exclude or include natural enemies at Kabete (left) and NHRC, Thika (right).

The populations of syrphid larvae at both sites were low (Fig. 18). For the majority of weekly observations, more syrphid larvae were recorded on glue and control treatments than on the lambdacyhalothrin ones. However, there was no overall effect (p=0.302).

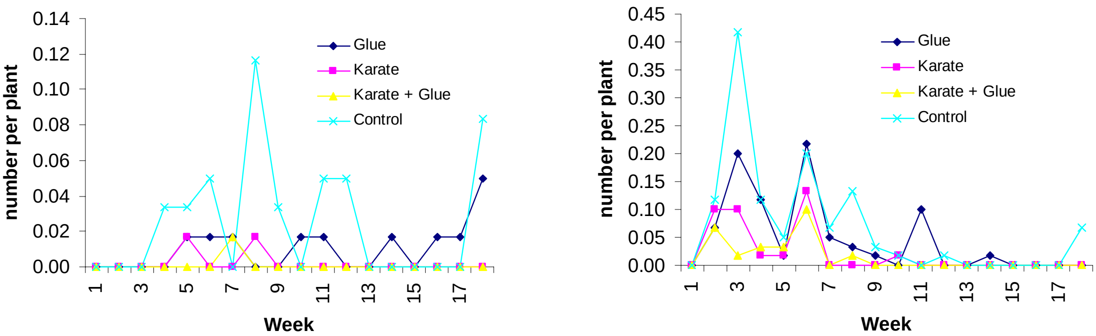


Figure 18: Population of syrphid larvae on kale plants exposed to different treatments to exclude or include natural enemies at Kabete (left) and NHRC, Thika (right).

There was no significant difference in the marketable yield of kale from the different treatments (p=0.233).

Conclusions

- Free access of natural enemies to DBM eggs leads to a significant mortality of this pest
- Procedures for estimating the predation and parasitism were established and have been refined during the current trials. The relatively small differences between predation/parasitism in the different treatments could have been due to the atypically low numbers of pests and their natural enemies.

Activity 2.3 Collect and identify entomopathogens which may be useful if other technologies need back up

During 2000 and 2001, extensive surveys of brassica crops were carried out on >100 peri-urban vegetable farms, covering 8 Districts located within 3 Provinces (Rift Valley, Central and Eastern) of Kenya, in order to identify indigenous entomopathogens of the three main genera of aphids (*Brevicoryne*, *Myzus* and *Lipaphis*) on brassicas. In total, >1500 leaves infested with aphid colonies were collected, stored in humid, plastic containers and incubated at 25^{o}C for a period of 2 days at CABI-ARC laboratories. Any hyphal growth emanating from the colonies was recorded, and fungal isolates transferred onto Tap Water Agar (TWA). After 2 days, fungi were single spored onto a fresh plate of TWA. Entomopathogens were isolated from aphids collected from 89 % of the farms. Taxonomic identifications of the fungi are currently underway at CABI – UK Centre in order to identify potential biocontrol agents, which could be developed into biopesticides against aphids in a subsequent phase of the project. A preliminary report (Appendix 4) shows two entomopathogenic fungi which attack aphids including *Aspergillus* sp. and *Alternaria* spp. The potential of these and other entomopathogens as biopesticides against aphids now requires further investigation.

Output 3. Cultural control methods tested
including use of disease resistant genetic material.

Activity 3.1 Assess the effectiveness and role of improved planting material
a. disease free seed b. seed selection (STB)

Healthy seed of a biotype suited to a given region is a good starting point for successful cultivation of crops. Smallholder farmers have stated (Cooper *et al.,* 1996) that seed quality from their usual retail sources is often poor, with a high incidence of seed-borne diseases, poor viability and unsuitability of inherent varietal characteristics for local growing conditions. One source of improved seed can be from self-selection and saving of seed between seasons. On-farm investigations were carried out to assess the status of on-farm vegetable seed production. It was found that in Kinale (Kiambu District) farmers already undertake their own seed production. When questioned, the farmers said that selection of plants for seed was based on a number of quality criteria. The important criterion for kale, which had stimulated the self-selection process, was the length of the productive season before the plants develop flowers, and ceased producing marketable leaves. Farmers informed the team that some commercial varieties had been found to ‘bolt’ early, reducing the season, and hence the productive life of the crop. Another criterion was levels of damage from pests and diseases, and any plants exhibiting damage-induced reduction in vigour or quality are grubbed out and destroyed or fed to animals. Only clean healthy, late flowering plants were used for seed production. If these methods could be proved to be effective, they could be disseminated to other areas as a valuable tool for improving planting material. In order to compare farmer-selected kale plants (Matharu) with the two most commonly grown commercial varieties (Thousand-headed and Collard) a series of four season long field trials were carried out at NHRC, Thika and Kabete, over the two rainy seasons during 2000. Prior to planting, 500 seeds (5 batches each of 100 seeds) from each variety were plated out onto TWA in order to test for viability and the presence of seed-borne pathogens. At each site, 36 plants of each variety were grown in each plot in a randomised block design with 5 replicates. Weekly observations were made on 20 randomly selected plants per plot. Pests and diseases, plant survival and plants coming into flower were recorded.

Results

Unidentified pathogens were recorded on the seeds of 0%, 0.02% and 3.8% of Thousand-headed, Collard and Matharu, respectively. Germination was 95.5%, 97.8% and 89.4% for Thousand-headed, Collard and Matharu respectively. Survival after 13 weeks was significantly lower for Thousand-headed plants than for either Collard or Matharu ($p<0.001$). There were also differences between sites with a higher percentage of plants surviving at Kabete (average, 80%) than NHRC, Thika (average, 60%).

One of the commercial varieties, Thousand headed, proved to be highly susceptible to black rot which reduced the field stand steadily (Fig. 19) at both sites from week 9. This agreed with farmers' information.

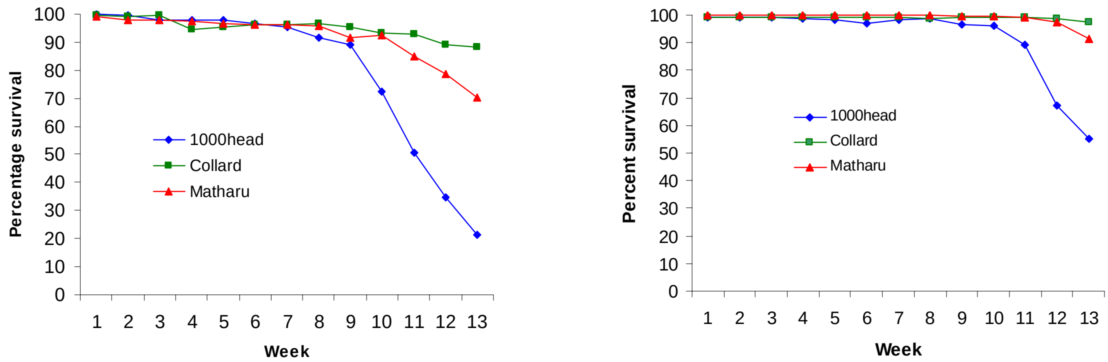


Figure 19: Survival of plants over 13 weeks at NHRC, Thika (left) and Kabete (right)

Marketable yield from the farmers' selection (Matharu) was similar to Collard ($p=0.15$), (Fig. 20) at 26 tonnes per ha of marketable yield and significantly higher than Thousand-headed ($p<0.001$). Numbers of the two most important pests (DBM and aphids) were not significantly different between the three different varieties of kale.

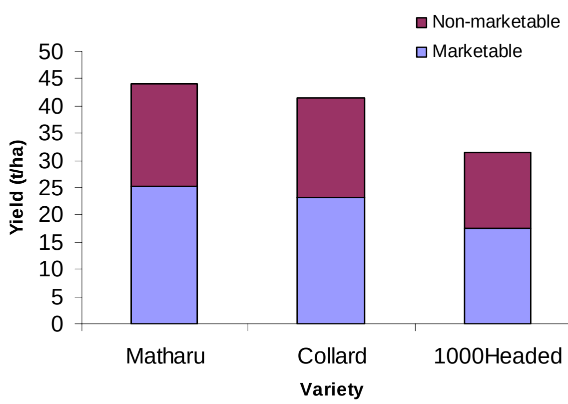


Figure 20: Total marketable and non-marketable yields of three different varieties of kale grown at NHRC, Thika and Kabete in 2000.

Conclusions

- The reported tendency of some commercial varieties to bolt (flower) was not observed in these four trials, but nevertheless results showed that farmers' self selected kale was equal or better than the two most commonly found commercial varieties at both sites. The methods of selection proved to be effective without any development by the project. These self selections are not made by the majority of kale growers, who buy seed. Self-selection could be a way of improving the quality and yield while reducing purchase cost of seed, and this information should be incorporated into the recommendations for vegetable IPM in future training activities. Moreover, research to develop more careful selection criteria could explore the potential for further improving the performance of this crop.

Activity 3.2 Assess potential usefulness of tomato germplasm which has genetic blight resistance

a. facilitate Kenyan access to AVRDC material **b.** field test superior material from current KARI experiments.

Late blight caused by Phytophthora infestans is the major constraint for tomato production in East Africa. Varieties currently available in Kenya are all highly susceptible to the disease, and under conditions conducive to disease development, tomato crops can be decimated. The Asian Vegetable Research and Development Centre (AVRDC) has developed some blight-resistant tomato lines (Hanson, pers. comm.) and it was agreed that the project would facilitate Kenyan access to, and assessment of, AVRDC germplasm through the Kenya Plant Health Inspectorate Services (KEPHIS). Excellent linkages were subsequently established with AVRDC's Africa Regional Programme (ARP) in Tanzania, but unfortunately, it transpired that the blight resistant lines had not gone through sufficient generations in Africa to allow their release prior to 2002. As an alternative, AVRDC-ARP made available to the project, four 'superior' tomato lines with resistance to Fusarium, Verticillium, and Root knot nematode.

Trials were carried out during the short rains in 1998 as part of an MPhil Thesis, to compare the pest/disease resistance and yield of the commonly grown, local varieties of tomatoes i.e. Money maker, Cal J, Roma and Arletta at two contrasting sites (Nyathuna and Karigu-ini). Subsequently, in 1999, imported varieties from AVRDC were compared with commonly grown local varieties, under Kenyan conditions, at two contrasting sites (NHRC, Thika and Kabete). These trials took place in two consecutive growing seasons (short rains in 1999 and long rains in 2000), using a randomised block design (4 replicates) to ascertain and compare their performance. Details of the varieties tested are: - from AVRDC, ARP 365-2-5, ARP 365-3-25, Tanya and Tengeru 97 and locally available varieties; Money maker, Roma, Cal J and Marglobe. Samples from each of the AVRDC lines were tested by KEPHIS to determine seed health and viability before release for the field trials. The levels of pest and disease were monitored weekly throughout the season, and at the end of the season for root knot nematodes (RKN). Growth habit (determinate or indeterminate), fruit setting and yield of each variety was noted.

Results

In 1998 and 1999, no pesticides were applied to the crops, and at all sites the crop succumbed to late blight by week 11. As a consequence, there was no fruit set and the yield was zero. There were no notable differences in the trends of early and late blight between the different varieties of tomato (Fig. 21), and the severity of blight meant that it was not possible to assess the incidence of other diseases. In the following growing season, the systemic fungicide Ridomil (metalaxyl) was sprayed according to manufacturers recommendations in order to control early and late blight. Again, there was no notable difference in the trends of early or late blight. Neither of the sites at which the trials were conducted appears to be particularly important for *Verticillium* or *Fusarium* wilts on tomato, and because of the severity of blight it was not possible to assess the level of either of the two wilt diseases. However, susceptibility to nematodes did vary between the different tomato varieties (Fig. 22), with Roma, Tanya and Tengeru showing more tolerance to RKN ($p<0.05$ for each comparison). Aphids (*Myzus* spp. and *Macrosiphum* spp.), whiteflies (*Bemesia* spp.) and bollworms (*Helicoverpa armigera*) were observed in the crop at both sites, although the numbers were too low to enable valid statistical analysis. Highest yields were obtained from two existing commercial varieties, Moneymaker and Roma (Fig. 22).

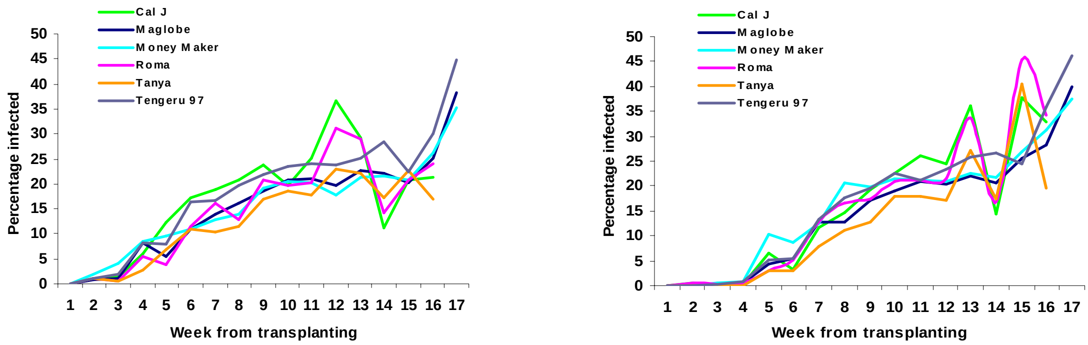


Figure 21: Temporal progress of early (left) and late (right) blight on 6 varieties of tomatoes grown at two contrasting sites during the long rains 2000

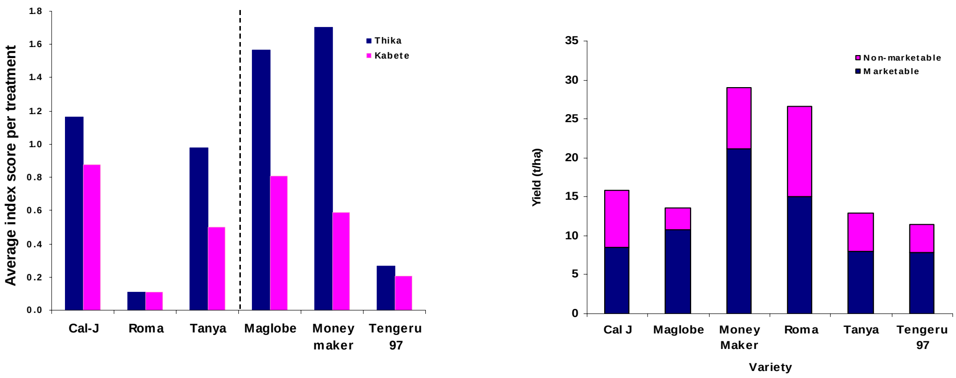


Figure 22: Graphs showing scores for (left) Root Knot Nematode galling and (right) total and marketable yield of six different varieties of tomatoes grown at two contrasting sites during long rains 2000

Conclusions

- Late blight is the key limiting factor to tomato production
- AVRDC germplasm was not superior, in terms of yield or disease resistance, to existing commercial varieties in Kenya.
- On the basis of these results, the variety, Roma could be recommended in areas where RKN is a constraint to tomato production.
- Assessment of new AVRDC blight tolerant varieties, which should be ready for testing in March 2002 will be a priority for the proposed validation and promotion phase of the project

Output 4. Integration of appropriate chemical, cultural, genetic and biological control options into an IPM strategy for major vegetable pests and diseases.

Activity 4.1 Evaluate the potential contribution of hand-picking pests as a component of an IPM strategy

One aim of the work was to find non-pesticide methods of controlling key pests. In any case, pesticides are not always available to/affordable for small-scale farmers during sporadic upsurges in pest numbers. Under these circumstances, hand-picking of some pests may be an appropriate technology which can significantly reduce pest numbers with no adverse effects on beneficial organisms or health risks to the farmer.

Field trials were conducted at two contrasting sites (NHRC, Thika and Kabete) over three consecutive growing seasons (1999-2001) to evaluate the effectiveness of hand-picking as a management strategy for DBM and aphids on brassicas. Four treatments were compared for their effectiveness against pests of cabbage: Weekly hand-removal ('hand-picking') and squashing of all insect pests; application of lambdacyhalothrin – the most popular inorganic chemical pesticide currently used by vegetable farmers in Kenya, sprayed according to manufacturers recommendations; weekly applications of a botanical concoction recommended by the Kenya Institute of Organic Farmers (KIOF) which consists of Mexican marigold, chillies, soap; and a control treatment. The experimental design throughout all five trials was a randomised block design consisting of four replicates each containing four plots – one for each treatment type, giving a total of 16 plots per trial.

Data were recorded at weekly intervals, just prior to treatment application, as follows: Weekly counts and scores of insect pests and their associated natural enemies on 15 plants per plot selected randomly each week from within the plot.

Results

Plots treated with lambdacyhalothrin had the highest number of DBM ($p<0.001$). There was no significant difference ($p=0.348$) between the DBM populations in the remaining treatments. Lambdacyhalothrin led to the lowest level of DBM parasitism ($p<0.05$ compared with any other treatment) whereas the KIOF concoction had significantly higher levels ($p<0.05$) than the untreated control (Fig. 23).

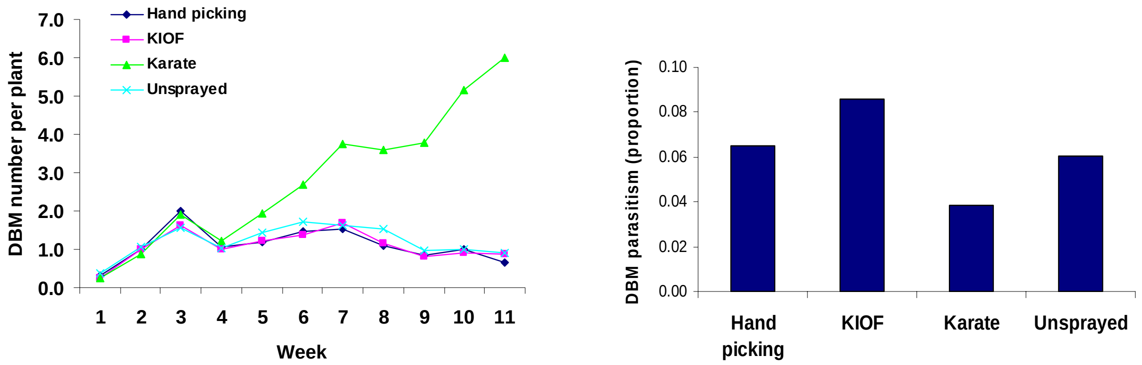


Figure 23: Effect of different treatments on the populations (left) and parasitism (right) of DBM

Handpicking was more effective than the untreated control for aphids ($p<0.001$) (Fig. 24), but again the particular KIOF concoction used in these experiments had little effect on aphids ($p=0.045$). Lambdacyhalothrin controls aphids well ($p<0.001$) but also appeared to suppress syrphid numbers ($p<0.001$). Unexpectedly, handpicking also appeared to reduce syrphid numbers (p<0.01). Again, lambdacyhalothrin resulted in the lowest levels of aphid parasitism (p<0.05).

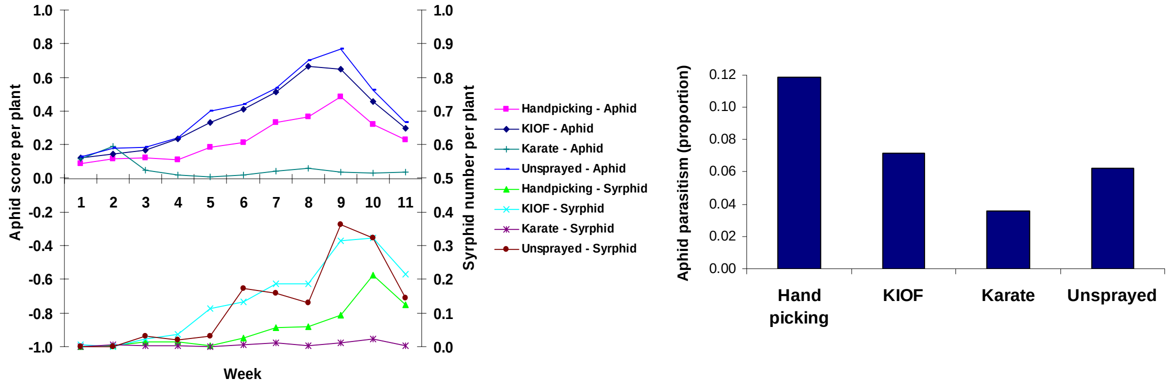


Figure 24: Effect of different treatments on the population dynamics of aphids and syrphids (left) and on parasitism of the DBM (right)

The time taken to handpick pests throughout an entire growing season was comparable to the time taken to apply pesticide (Fig. 25). For handpicking, time increased as the plants got bigger and infestations got heavier, but even at the end of the season, time was still less than a minute per plant. Treatment with Lambdacyhalothrin led to significantly (p<0.001) higher yields than other treatments. The yields from other treatments were not significantly different from the control.

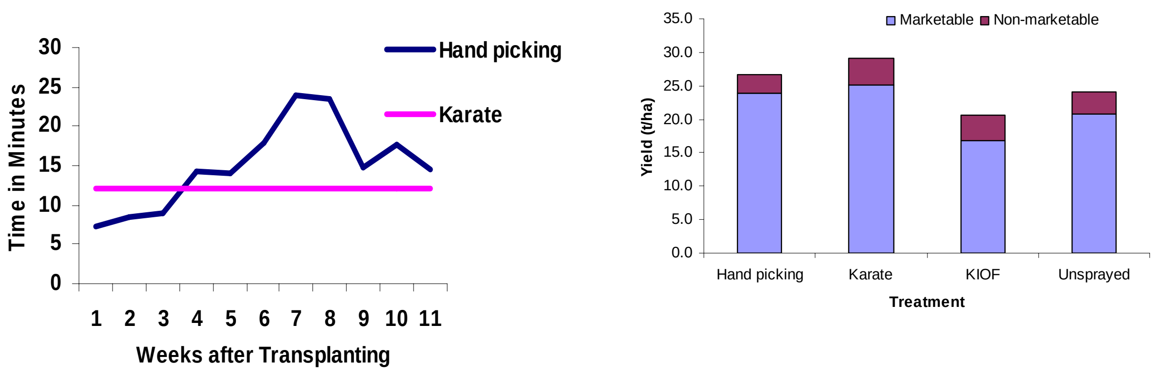


Figure 25: Graphs showing time taken to handpick pests in comparison with spray application (left) and average marketable and non-marketable cabbage yield

Conclusions

- Handpicking does not appear to be an effective method of controlling DBM but could be viable for aphid control on small plots.

Activity 4.2 Develop preliminary recommendations and farmer friendly information *materials. Compare knowledge transfer mechanisms in small-holder vegetable production systems*

Smallholder farmers need to have access to information on IPM technologies in order to better manage pests and diseases within their cropping system. Furthermore, these technologies need to be integrated using farmer participatory approaches to ensure that the component technologies are effective, sustainable and complementary. The more subtle pest management approach relies on a greater understanding of both the pests and diseases, together with improved awareness of the inter-relatedness of new IPM strategies available to them.

The project has tested a range of different approaches in order to ensure the successful uptake of outputs. These have included a range of farmer-participatory activities including on-farm trials (Fig. 26), farmer managed experiments, workshops, farmer field days and Newspaper articles e.g. an article in the Daily Nation Newspaper (Appendix 1), Agricultural Magazine articles such as those in the HCDA magazine (Appendices 2&3) and scientific presentations e.g. SIUPA, Zambia. Constructive links with industry have included discussions with spray application specialists e.g. Hardi Kenya Ltd, joint experiments with agro-chemical companies e.g. Syngenta, Vegetable exporters e.g. Homegrown and Biopesticide companies e.g. Dudutech.

To date, the project has funded the preparation, design and printing of 2000 calendars. These are in two sizes: large wall calendar for small-holder farmers and NGOs, together with small desktop calendars for office based stakeholders (see Fig. 27). 5000 farmer-friendly posters have been distributed to target beneficiaries including agricultural NGOs, CBOs and Ministry of Agriculture Extension Departments as well as smallholder peri-urban vegetable farmers and agricultural retail outlets.

Figure 26: Farmers at a field day discussing seedbed techniques

During Phase 2, promising technologies including selective pesticides, improved application practices, using V lance technology, sprays based on botanicals, biological pesticides such as *Bacillus thuringiensis* (Bt), cultural practices including Farmer Seed Selection, hand removal of pests, trash burning, hot water, and resistant varieties have been assessed and tested either on-station or on-farm. The next stage is to incorporate them into the 'Habitat Management Based' (HMB) which relies primarily on managing the habitat such that pests and diseases are regulated naturally as far as is possible, supplemented when necessary by use of biorational and botanical products and narrow spectrum synthetic pesticides.

Output 5. Successful co-ordination of CPP vegetable IPM projects in Kenya

Activity 5.1 Set up and implement co-ordination protocol and communication pathways.

Successful co-ordination involved bringing together the staff and resources involved with several different projects within the CPP vegetable IPM thematic cluster, in such a way that their activities could be carried out in a productive and integrated fashion. The four main projects in the cluster are the one reported here, and three others: R7449 Development of biorational brassica IPM in Kenya, R7472 Integrated management of root-knot nematodes on vegetables in Kenya, and R7571 Management of virus diseases of important vegetable crops in Kenya. There are also a number of smaller studies on uptake, adoption and promotion. Project co-ordination facilitated sensible scheduling of visits to Kenya by UK scientists involved with these projects, and thus avoided a situation in which several visits occurred at the same time - this would have caused a significant burden on in-country resources and scientists.

The co-ordinator in Kenya played a key role in organising land for experiments, arranging meetings with farmers and other stakeholders for all the projects, booking hotel accommodation at favourable rates, organising the transfer of funds from the UK to all collaborators based in Kenya, and ensuring financial accountability. The co-ordinator also managed the scheduling and maintenance of the two Land Rovers based at CABI for use by CPP projects, so that availability of transport enabled the fieldwork to be carried out according to the requirements of each research project.

The UK co-ordinator performed a liaison role and organised annual project cluster meetings in the UK. This involved all scientists working in the thematic cluster projects and CPP staff, preparing an agenda, booking facilities and accommodation for visitors from Kenya and the UK, and facilitating the meeting programme. Minutes from the meetings were circulated to all stakeholders. The co-ordinator facilitated information flow between personnel carrying out the different IPM activities on the ground, and the Crop Protection Programme staff, to whom occasional advice and briefings were given.

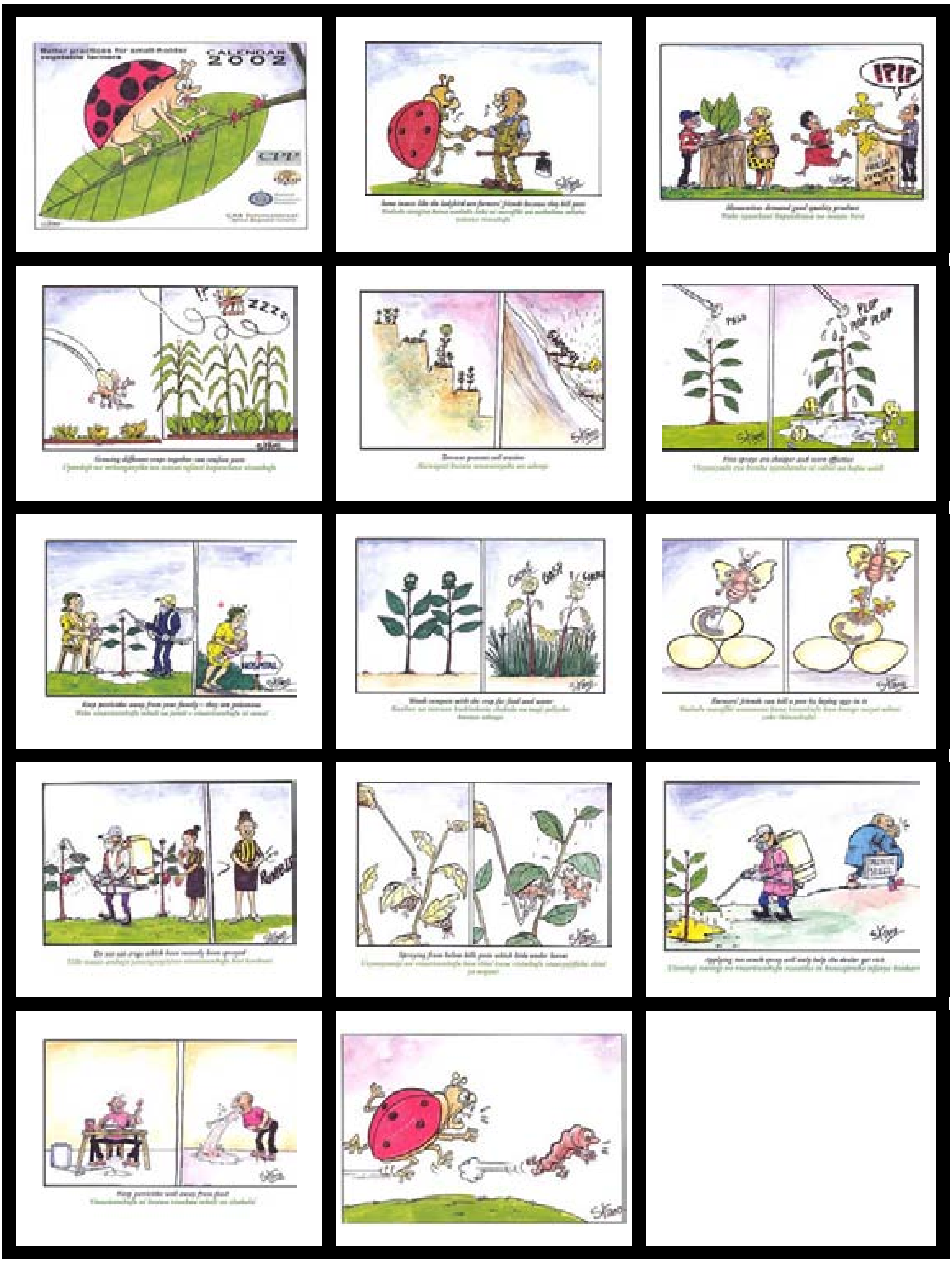


Figure 27: Cartoons depicting IPM component technologies which were commissioned by the project for the production of a calendar for small-holder farmers

Contribution of Outputs to developmental impact

A series of research 'products' resulted from the delivery of the project outputs. These pro-poor technologies, techniques, products and dissemination materials make a positive contribution to sustainable livelihoods in that they strengthen the capacity of peri-urban farming communities to manage pests in a more efficient way using less pesticide in ways which deliver better efficacy. They make vegetable production more viable and profitable especially when they facilitate production of crops under seasonal conditions normally accompanied by severe depredation from pests and diseases. Under these conditions, produce prices may increase by a factor of10 or more e.g. tomatoes in the rainy season – those who protect their crops successfully during these times reap rich rewards.

Improved application techniques (relating to Output 1)

- A package of low cost spray lance enhancements known as the V lance kit (a swivel joint and more appropriate nozzles) which produces more effective pest and disease control at lower doses. Project staff are in dialogue with the sprayer manufacturing industry to finalise plans for making the V lance available to farmers. A current project proposal involves initial distribution of a limited number of kits to small-scale farmers, together with training in their use. Training is considered necessary to prevent excessive application of the smaller, less visible spray in misguided attempts to 'spray to run-off'. The V lance will also be an integral component of the proposed validation and promotional phase of the current project, to be implemented by the current project team together with effective target beneficiaries such as SACDEP and the extension services. It will be used to apply biological and, where necessary, chemical pesticides on the demonstration farm for the habitat management-based approach. Promotion of the technology will take place via formal training, farmer-to-farmer contacts and mass media dissemination.
- A low cost spray additive (domestic detergent) which improves spray retention and spreading on brassica leaves at much lower cost than commercial wetting agents (adjuvants). This will result in better crop protection efficacy at lower doses. Biological efficacy trials are now required to demonstrate that the physical improvements are accompanied by improved efficacy.

Impact of Natural enemies (relating to Output 2)

- Experimental methods of comparing pest infestation levels when predators and parasitoids are excluded or included were developed. While results have been somewhat inconclusive to date, the methods show great promise for evaluating impact of these natural enemies. Further work will continue in the remaining months of the project to refine these techniques, quantify effects of different types of natural enemy and prioritise conservation practices which encourage these specific organisms. The techniques will also be adapted as tools for training trainers in the course of the proposed validation and promotion project.
- Rapid and effective pest, disease and natural enemy sampling techniques were developed during the course of the survey and field trial work. These will be adapted for farmer use as an essential tool in their decision-making on pest management interventions.

Improved planting materials (relating to Output 3)

- Identification of a locally available variety of kale which has been bred by farmer-selection for pest and disease resistance and late flowering. The superior qualities of this cultivar were demonstrated in comparison with two commercially available varieties and this evidence will inform the process of promoting this type of planting material.

IPM component technologies and their dissemination (relating to Output 4)

- Evidence strongly supports a strategy of crop monitoring to inform farmer decision-making on pest management interventions, in contrast to the frequently observed calendar spraying (spraying regularly regardless of infestation/infection levels)

- Efficacy and yield enhancement information on 5 potential DBM and aphid control products, together with information on their impact on predators and parasitoids. This information will be utilised in the development of crop-specific IPM strategies which will be promoted through the proposed validation and promotion project via the demonstration farm and farmer training and awareness raising.
- Roma was identified as the tomato cultivar of choice on smallholder soils known to have root knot nematode (RKN) infestations.
- The feasibility and efficacy of hand-picking as a pest control method was determined. Aphid control by handpicking was significantly more effective than the unsprayed control ($p < 0.001$) but not as effective as the lambdacyhalothrin spray treatment. While considered feasible on plots of up to 100 m^2 per hand-picking person, it was not significantly more effective than the unsprayed control at DBM control. The effect of handpicking on pest parasitism appeared negligible while there was some effect on syrphid numbers (major aphid predators).
- It is clear that some augmentation of the major natural enemies is required before they can exert an effective controlling influence on the pests.
- Dissemination materials and events – calendars and posters were produced as well as newspaper and agricultural journal articles. Significant numbers of farmers and extensionists were sensitised to IPM approaches through workshops, farmer days and visits.
- International experience and dialogue was fostered by a series of exchange study tours with a vegetable IPM project in Zimbabwe. This built confidence and allowed technical skill-sharing between scientists from the two countries.

Co-ordination (relating to Output 5)

- Effective co-ordination of project activities which tool place in the vegetable cluster. This allowed efficient working and information sharing between staff from 5 different organisations.
- Through close dialogue with the wide range of scientists involved in the cluster, pulling together candidate technologies from the various projects into potential IPM packages.

Dissemination Outputs

Edited Proceedings

OGUTU, W.O., MIANO, D.W. AND ODUOR, G.I. (2001). Evaluation of insecticides against major pests major pests in the peri-urban vegetable production system of Nairobi, Kenya. (2001). In 4th International Entomological Society of Zambia, Lusaka, 19-20 April 2001 Proceedings

ODUOR, G.I. AND KIBATA, G.N.(2000) IPM in Peri-Urban Vegetable Production Systems in Kenya. Proceedings of the CGIAR Strategic Initiative on Urban and Peri-urban Agriculture Stakeholders meeting and Planning Workshop, Sub Saharan Africa, Nairobi, 1-4 November 2000.

Farmer Field Days

1. Kagunjo;s Farm

Open Days

KARI Open Day: Improved Vegetable Production. National Agricultural Research Laboratories, November 2001.

Institute/organisation/internal reports

COOPER, J and GRZYWACZ, D. (1999) Minutes of Kenya project cluster meeting held at NRI 22-30 November 1999.

COOPER, J and DOBSON, H. (2000) Notes on third Peri-Urban vegetable project cluster meeting held at NRI, 20th and 21st November 2000.

KIBATA, G.N. (2000) Investigations of insecticide resistance in the Diamond-back moth, Plutella xylostella L. In KARI Research Highlights

KOECH, S. and KARANJA, P. (2000) Peri-urban vegetable pest management project. On farm pesticide application trials - Improved lances and nozzles.

MIANO, D.W., KIBATA, G.N. and KOECH, S.(2000) Pest management in horticultural crops; an integrated approach to vegetable pest management with the aim of reducing reliance on pesticides in Kenya. *In KARI Research Highlights.*

MIANO, D.W; KOECH, S. and KIBATA, G.N. (2001) Pest management in horticultural crops; an integrated approach to vegetable pest management with the aim of reducing reliance on pesticides in Kenya. *In KARI Research Highlights.*

ODUOR, G., SIMONS, S. and KIBATA, G. (2000) Report of an experiment comparing the performance of tomato varieties from AVRDC Arusha, Tanzania. CAB International – Africa Regional Centre.

SIMONS, S., KIBATA, G and ODUOR, G. (2001) Report of an experiment comparing the performance of tomato varieties from AVRDC Arusha, Tanzania. CAB International – Africa Regional Centre.

Series of back to office reports by NRI staff, J Cooper and H Dobson over period 1999-2002.

Newsletters

1. SIMONS, S.A. (1999) More activities in vegetable IPM. *In CABI in Africa (CAB International Newsletter for Africa).* 8pp.

2. ODUOR, G.I. (2001) Tomatoes ‘au lait’. *In CABI in Africa (CAB International Newsletter for Africa).* 8pp.

Newspaper Articles

‘A Friend Indeed’ promoting the outputs of the project, which appeared in The Daily Nation Newspaper, Thursday May 10th 2001 (see appendix 1)

Magazine Articles

1. COOPER, J.C., KIBATA, G and ODUOR, G. (2001) Using pesticides wisely. In *Horticultural Crops Development Authority - Horticultural News* (May 2001 issue), pp 10-12.

2. KIBATA, G., COOPER, J.C., and ODUOR, G. (2002) Better Targeting of Sprays. In *Horticultural Crops Development Authority - Horticultural News* (Jan/Feb 2002), pp 9-11.

Posters

1. Some insects like ladybirds are farmers friends because they kill pests.

2. Fine sprays are cheaper and more effective.
3. Spraying from below kills pests which hide under leaves.
4. Keep pesticides well away from food.
5. Ladybirds kill and eat harmful pests like caterpillars.

Calendars

1. Large wall calendar for small-holder Vegetable farmers (2002)
2. Small desk-top calendar of better practices for smallholder vegetable farmers (2002)

MPhil/MSc Theses

ABDULLAHI, D. KHALIF (2001) Study of the efficacy of chilli and onion aqueous extracts as natural pesticides for control of insect pests of tomato with emphasis on the African Bollworm, *Hellicoverpa armigera* (HB) (Lepidoptera: noctuidae). *Master of Science, University of Nairobi, Kenya.* 136pp.

KARANJA, D.K. (2001) Epidemiology and Control of Late Blight (Phytophthora infestans) on Tomato (Lycopersicon esculentum): A Study in Small-Holder Farms in Kenya. *Master of Philosophy in Botany (Plant Pathology), Moi University, Kenya.* 112pp.

Video

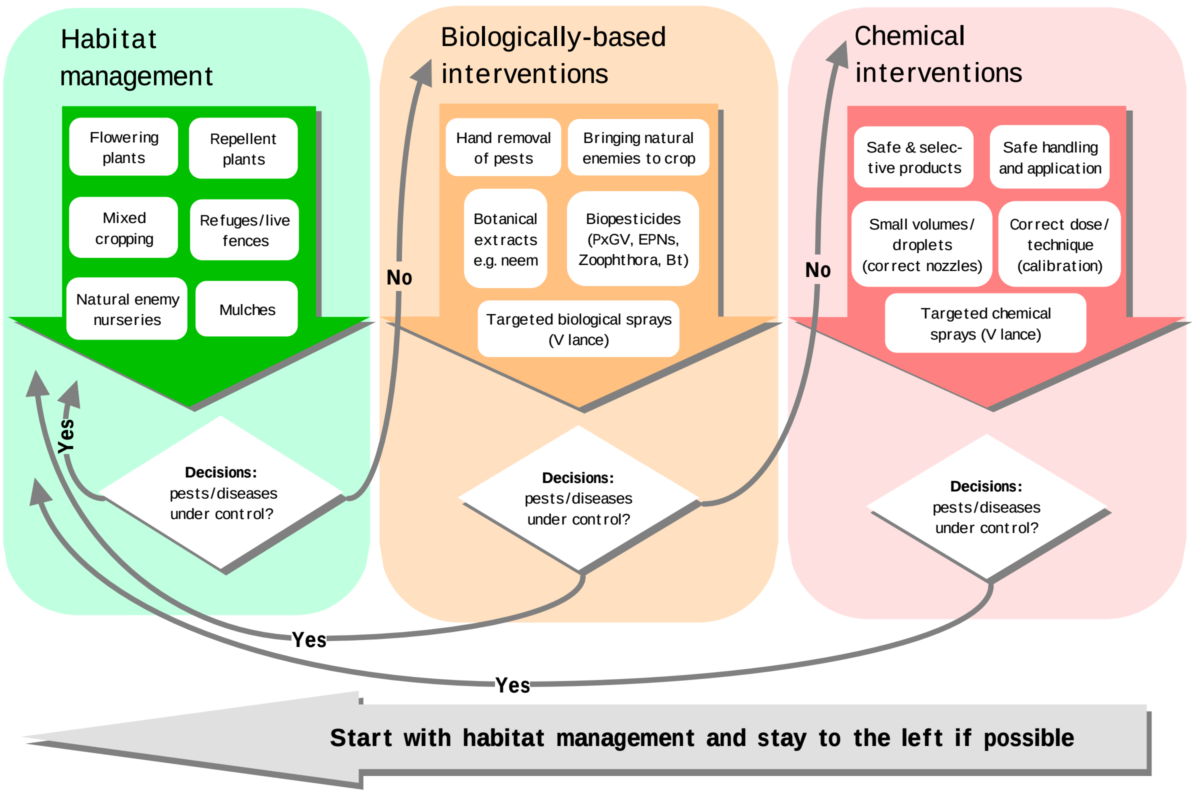
Farmer participatory meeting on 'IPM Technologies' at Kagunjo's farm, Nyathuna, March 2002.

Promotion pathways and follow-up action

Further stages are required to add value to these research products. For example, continuing collaboration with industry is expected to result in improved spraying equipment being available in a market sensitised to their benefits.

The component technologies developed in this project, together with those from other cluster projects and from further afield, provide a selection of tools which can be assembled to form various crop-specific pest management strategies within a broader Habitat Management Based (HMB) approach. The deployment of these technologies within each strategy will be tri-partite, starting with techniques relying principally on habitat management, such as natural enemy nurseries and flowering plants, underpinned by better known cultural practices such as rotations, field hygiene and appropriate cultivar choice. Monitoring of pest, disease and natural enemy numbers provide the necessary feedback for timely interventions if and when the need arises. These interventions constitute a shift to the second tier of the proposed approach and are biologically-based in order to allow continuing expression of natural regulatory pressures and if possible, reinstating them as the principle processes protecting the crop. If/when biologically-based interventions are insufficient to maintain pests and diseases at acceptable and non-injurious levels, then chemical interventions are available as a last resort. Even these are chosen and used in ways to minimise disruption of the natural regulatory processes and biological interventions. The principle of this three tier approach, illustrated in Figure 24, is expected to result in cheaper, safer and more effective pest management for smallholders, together with safer working practices for farmers and labourers and safer produce for consumers.

Figure 1. Habitat Management-Based (HMB) approach to reduce reliance on pesticides



In the continuum from research to uptake, the project is now ready to validate the HMB approach and to begin to promote it to a wider constituency of users.

The partnerships, methods and expected outcomes of this initiative are detailed in a project memorandum submitted to CPP (October 2001) entitled: *Validating and promoting more sustainable pest management strategies for small-scale vegetable farmers in Kenya.* This complements a proposal for EU support (September 2001) entitled**:** *Improving the sustainability of peri-urban vegetable production by smallholder farmers in eastern and southern Africa*.

Appendix 1: Newspaper article entitled, ‘A Friend Indeed’
promoting the outputs of the project, which appeared in The Daily Nation Newspaper

A friend indeed

Not all insects are trespassers

By OGOVA ONDECO

Now that its official the Government will no longer offer extension services to farmers, then it is only wise they make as many other friends as possible.

Somebody is already helping them to identify these. Scientists from Kenya Agricultural Research Institute, Centre for Applied Biosciences International and Natural Resources Institute are telling the farmers to start right at the shambas.

This work is part of a larger research programme on Integrated Pest Management (IPM) of vegetables, funded by the British Government's Department for International Development, through its Crop Protection Programme.

According to Dr George Oduor, a senior scientist at CAB International, vegetable farmers in Kenya rely heavily on the use of chemical pesticides to control pests and diseases, which is leading to increased concern about residues in produce, operator exposure to harmful pesticides, development of pesticide resistance and environmental damage.

The cost of pesticides, he says, absorbs a significant proportion of farmers' income. He says, most farmers are unaware that one of the best alternative pest control options can be found right in their shambas.

'Farmers' Friends' are helpful dudus such as insects, spiders and mites, which kill pests and prevent them from destroying crops. The ladybird beetle, for instance, is known to feed on pests such as aphids, bollworm and other caterpillars, that damage crops.

Dr George Oduor says that research done in Eastern, Central and Rift Valley provinces revealed that four main crops (cabbage, kale, tomato and spinach) account for over 95 per cent of peri-urban vegetable production. But, that these vegetables are all prone to insect pests and diseases.

Diamondback moth, aphids and semi-looper caterpillars are the major pests that attack cabbage and kale, while leaf miner, aphids, bollworm and thrips are more important on tomato and spinach.

Although diseases are not usually important on cabbage and kale, black rot, downey mildew and viruses can be a problem in some areas. In contrast, early blight, late blight, virus and leaf spot are extremely damaging on spinach or tomato.

A comparison of shambas where pesticides were used (conventional) with those in which no pesticides were used (organic) revealed that the number and types of farmers' friends are clearly higher in the latter.

Farmers' friends come in many forms including predators which catch and eat harmful insects and mites, parasitoids which lay eggs in or on harmful insects, and pathogens like fungi, bacteria & viruses which can kill harmful insects. Predators work like cats which catch and eat rats.

An example is the ladybird beetle and hoverfly larvae, which feed on aphids that suck plant juices. Parasitoids work very much like jiggers. A good example of a parasitoid is a tiny, parasitic wasp which find a living aphid the ideal home for its developing young.

Aphids on leaves often become dry and shiny, instead of moist and healthy-looking because their bodies conceal developing parasitoids which suck away their life from within.

Pathogens can kill harmful insects in the same way as humans can be killed by diseases such as the Ebola virus. A good example in the shamba is the virus, *Plutella xylostella* granulosis virus or PxGV for short, which causes caterpillars of the green, diamondback moth to become yellow and swollen as their bodies fill with the disease just before death.

These pathogens can be isolated from crop pests, formulated and incorporated into sprays applied to control the same pest from which they were isolated.

Pathogen-based sprays are not yet widely available, especially for vegetable pests, but PxGV is currently under development for use here in Kenya. PxGV does not affect other animals, or even other insects, so is safe to consumers (of crops) and spray operators. Unfortunately if two types of pests occur together, farmers would need to apply a second pathogen to kill the other pest.

However, pathogens have the important advantage of not harming Farmers' Friends so they work together, unlike most chemical pesticides.

It is not always easy for farmers to distinguish their 'friends' from their 'enemies' as some friends are easier to recognise than others.

Predators such as ladybird beetles, spiders and predatory ants are easy to distinguish, whereas parasitoids such as parasitic wasps may be easily mistaken for flies or biting wasps.

One of the prime objectives of the on-going research programme is to raise awareness amongst farmers and Ministry of Agriculture extension staff of the identity, importance and potential benefits of farmers' friends.

This is being done through workshops, farmer participatory meetings and various farmer-friendly publications.

How can farmers encourage their 'friends' in the shamba? Growing flowering plants on the margins of the shamba attracts adult stages of farmers' friends, which feed on their nectar, then reproduce on the harmful insects.

The French marigold is an example. Similarly, intercropping with crops, which flower, such as beans will also encourage farmers' friends and create refugia where farmer's friends can hide or rest.

Although newer, more pest specific pesticides are becoming available, most existing products kill farmers' friends as effectively as they kill the enemies (pests). For this reason, farmers should be encouraged to have a good look at their crop to assess the pest numbers, and only spray if really necessary.

Not only does this reduce the negative impact on farmers' friends but it also reduces the number and cost of pesticide applications.

The take home message is that not all dudus in farmers' shambas are enemies!

Dr George Oduor can be contacted at, CAB International – Africa Regional Centre, P.O. Box 633 Village Market, Nairobi (g.oduor@cabi.org).

Appendix 2 From HCDA Horticultural News Journal (May 2001)

Using pesticides wisely

J. Cooper (NRI), G.N. Kibata (KARI) and G.I. Oduor (CABI)

Natural Resources Institute

Kenya Agricultural Research Institute

CAB INTERNATIONAL
Africa Regional Centre

There is increasing pressure for growers of vegetables and other crops to be more conscientious with their methods of pest control. The organically produced crops, much preferred by some lobby groups, only constitute about 3 percent of the market in Europe and are still on the horizon. For the more conventional farmers the shift in emphasis is to reduce the number of toxic chemical sprays to a bare minimum and allow other pest control factors such as pests natural enemies or resistant varieties to gain prominence in the reduction of crop losses instead of solely relying on pesticides. Notwithstanding these considerations the majority of Kenyan fresh produce growers will continue to use pesticides to control pests in order to meet the phytosanitary and quality standards of the overseas markets.

There has been much discussion recently on how the EU pesticide harmonised legislation will affect farmers in ACP exporting countries as well as the producers within Europe. Some important pesticides currently used in horticulture will be phased out as they fail to meet the stringent minimum residue requirements of the European market. Other pesticides allowed for specific crops will therefore have to be used judiciously to ensure that the crops reach the market with residues below the maximum residue level (MRL). One way to achieve this is to ensure that no more than the recommended dose of the pesticide is applied and that pre-harvest periods are strictly observed. We have been exploring methods of improving the way pesticides are used on horticultural crops. We report below some of our findings.

Getting the correct dose onto crops

All growers need to be sure that the dose they apply is correct, and will usually believe that they are doing so. However a series of detailed observations carried out by scientists from KARI (Kenya Agricultural Research Institute), together with CAB International (Centre for Applied Bioscience International) and NRI (Natural Resources Institute) showed that some smallholder farmers were applying from only a third of the recommended dose rate to five times the rate given on the label. The study was part of a much larger research programme on Integrated Pest Management (IMP) of vegetables which is funded by the British Government's Department for International Development, (DFID), through its Crop Protection Programme. It also revealed that less than 15% were within 10% of the recommended dose. It is believed that this applies to other growers too, and this is borne out by market basket surveys in Nairobi which have detected residues higher than the MRL. The risks to consumers are obvious. For exporters the increased checks and traceability of produce could lead to loss of markets in the EU if MRLs are exceeded.

There are two main reasons for incorrect dosing.

1. the farmer puts too little or too much of the concentrated pesticide into the sprayer tank each time he/she refills it
2. the farmer applies too little or too much volume of spray liquid to the crop

This is how dosing problems occur, but what are the reasons for it?

- pesticide labels give application advice in different and sometimes confusing forms;
- the writing on the label is often small and difficult to read;

- the farmer may have no accurate way of measuring the correct volume of concentrate;
- the area being treated may not be accurately measured;
- calculations are sometimes necessary, which not all farmers find easy;
- sprayer nozzles are often too big resulting in very high volumes being applied;
- farmers sometimes like to spray until the plant is dripping - something which pesticide labels sometimes encourage with the instruction to 'spray to run-off'

Dosage instructions are given on the pesticide label and can be expressed in one of several ways:

1) Active ingredient (a.i) dose: the weight of active ingredient per hectare is given i.e. 5gm a.i. per hectare. Many farmers and operators cannot convert this instruction to a useable recommendation.

2) Concentrate dose: the volume of concentrated pesticide which should be applied per hectare is given i.e. 1 litre per hectare. This is somewhat easier to understand but calculations are required to work out how much pesticide and water should be mixed together.

3) Tank dose: the volume of concentrated pesticide to add per 10 litres of water (which is the volume held by some knapsack sprayers). This 'tank dose' is the simplest method of recommending a dose, although basic calculations are still required for tanks of more or less than 10 litres.

When a tank dose (3) is given, some labels also state the area which must be covered by each knapsack load, or a guide volume to be applied over a given area, known as the volume application rate (VAR). The tank dose method assumes a certain VAR and the dose of active ingredient per area is only correct at this VAR. If a larger volume of spray liquid is applied, then the dose will increase. Of course the active ingredient required will vary between different types of crop and between different ages of crop - a crop which has just been transplanted will require much less active ingredient to treat its small leaf area than a fully grown crop. To some extent, this is a self compensating system where farmers are bound to apply larger volumes on large plants, which will deliver the higher dose needed by its greater leaf area and number of pests. However, tank dose advice on labels is sometimes accompanied by figures for one of the other two methods (1 or 2) on the same label. Calculations using this label data show that manufacturers often give tank dose recommendations on the assumption of a VAR of 200 l of water /ha when in reality farmers are often using over 1000 l/ha. This results in a five times overdose of the active ingredient.

How can the sprayman get it right?

Step 1. Measuring volume application rate (VAR)

Before a farmer can be sure he is using the correct dose of pesticide on a particular crop, he must know his VAR. This can be done as follows for knapsack sprayers. The technique can be scaled up for tractor-mounted sprayers.

Measure out a square area of the crop. For knapsack sprayers, an area 5 metres (5 big paces) long by 5 metres wide is large enough. It will give an area of 25 square metres ($25m^2$) or 1/400th of a hectare
Mark the corners with sticks.
Now put the sprayer on a level surface and put water into the tank (no pesticide) up to a mark on the sprayer tank.
Spray the marked out area of crop in a normal way
Put the sprayer back onto the same level surface and, using the volume markings on the sprayer, estimate the volume that was sprayed onto the crop.
If, for example, the volume used was 1 litre, this corresponds to a VAR of around 400 l/ha. If the volume used was 1/2 litre, this corresponds to a VAR of around 200 l/ha.

Step 2. Adjusting volume application rate (VAR)

If the volume used on 25 m^2 was more than 1 litre, this will give a VAR which is too high for most crops, and generally this will be wasteful on pesticide. The farmer should either fit a smaller (finer) nozzle to the sprayer, or, if the nozzle is already small enough, he should modify his spraying technique to apply less spray to each plant i.e., spend less time spraying it. After these equipment and/or technique adjustments, the farmer should measure VAR again to make sure it is less than 400 l/ha. A reasonable test of flow rate is to measure the spray from the nozzle over a minute. Pump at the normal rate. If the flow rate (for insecticides and fungicides) is more than 1 litre per minute, the nozzle is probably too coarse. It may be worn or a type with a hole which is too large. Herbicides are normally applied using larger drops and higher VARs, so a coarse nozzle is actually needed.

If the spraying equipment is not capable of producing the correct VARs (less than 400 litres per hectare) - for example if he has no way of replacing a very large nozzle - the sprayman must then make adjustments to the tank dose to compensate for this. For example if the sprayer is putting a VAR of 800 l/ha on a medium-sized crop (at least double the right VAR), the tank dose can be reduced to half of what the pesticide label says without any risk of applying too little active ingredient. This process of ensuring correct spray volumes are used is called calibration, and its importance cannot be over-emphasised.

Step 3. Putting in the right tank dose

The label will usually give a volume of concentrated spray liquid (or weight of dry powder) to put in each 10 litres of water. Sometimes, the advice is given for 15 litre sprayer or for 100 l of water, but the amount required for a particular tank volume can be worked out fairly simply. For example if the label recommendation states that 20 ml of pesticide concentrate must be put into every 10 litres of water and the farmer is using a sprayer which contains 15 litres of water, the amount to be added can be worked out as follows: 15 litres is one and a half times the volume of 10 litres which the tank dose recommendation is based on. Therefore one and a half times the tank dose recommendation for 10 litres must be added. One and a half times 20 ml = 30 ml.

Once the volume required per sprayer tank has been worked out, the farmer needs a small measuring cup to make sure he puts this required amount into the sprayer. A measuring cup should be provided by the shop when the pesticide is bought, but if is not, the farmer should borrow one from a friend if possible. If there is really no possibility of using a measuring cup, the lid of the pesticide bottle can be used to measure small volumes, so it is a good idea for the label to state the volume of the cap.

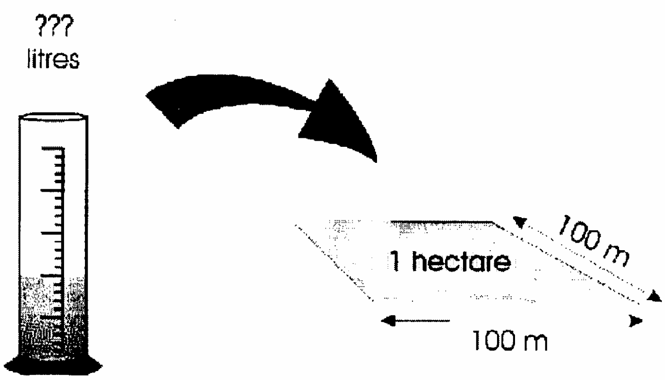


Diagram – some labels give a volume per hectare

Conclusions

- Overdosing or under-dosing crops can immensely diminish the value of the produce either by exceeding MRL or failing to achieve the desired level of pest control.
- The correct dose of a pesticide can only be achieved by ensuring that precisely measured volumes of spray are applied per unit area.
- In general we must try to ensure that volume application rate is some-where between 200 and 400 L/ha (or even less for very small plants).

Only 15% of applications were found to be within 10% of the recommended dose rate

NOTE: More articles on improved targeting of sprays will appear in the next issue of HCDA Horticultural News.

For further information, please contact G.N. Kibata, KARI–NARL, PO Box 14733, Nairobi (cpp@net2000ke.com) Tel: 443956/58

Appendix 3 Better targeting of sprays - from HCDA Horticultural News Journal

CAB INTERNATIONAL
Africa Regional Centre

Kenya Agricultural Research Institute

Natural Resources Institute

BETTER TARGETING OF SPRAYS

G N Kibata, J Cooper & G. Oduor

Last months article on the need for applying the correct dose when applying pesticides to control pests and diseases told half the story on good spray application. Equally important is spray targeting distributing the active ingredient in the right place on the crop. This requires that the spray be applied in the form of the appropriate sized drops, that the spray be emitted in the correct direction and that the volume is not excessive.

Correct atomisation

Drop size is crucial to good pesticide distribution. Most sprayers used in Kenya use a hydraulic nozzle such as a hollow cone or fan nozzles, to break up or atomise the spray liquid. When new, hydraulic nozzles produce a wide range of drop sizes, termed the size spectrum. As they wear out this spectrum gets wider, and drops get larger. The flow rate increases too as nozzles wear, and the farmer inevitably applies a very large volume of spray which is likely to result in an overdose of active ingredient. Over-dosing wastes money, but more importantly is liable to leave high residues on produce which may exceed the maximum residue level (MRL) when the crop is harvested. Unnecessarily big drops tend to bounce off or run off the leaves more than smatter drops. A medium to fine nozzle is therefore best for applying fungicides and insecticides. These give good coverage of the crop with many small to medium sized drops, many of which wilt be around 200 microns. Measuring the flow rate gives an indication of whether the nozzle is too coarse, damaged or worn. By spraying at normal pumping rate over a timed period (e.g. 1 minute) and collecting the spray in a bucket or other container, the flow rate can be measured. Anything over 800 ml (0.8 litres) per minute is likely to be too coarse, and a replacement nozzle is probably needed. Uneven output across the nozzle also indicates wear or damage and that the nozzle should be replaced. As farmers procure sprayers they should ask the dealer for a fine to medium nozzle for spraying any insecticide or fungicide.

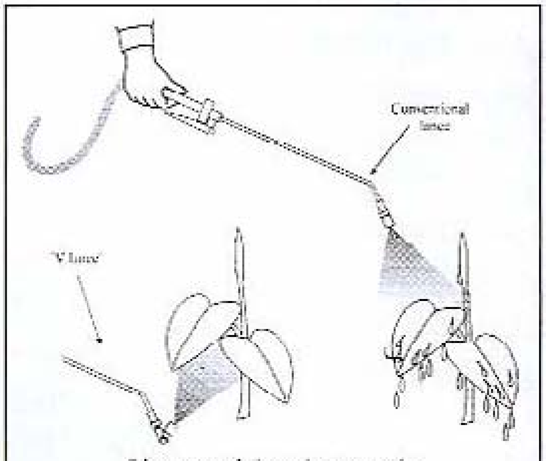
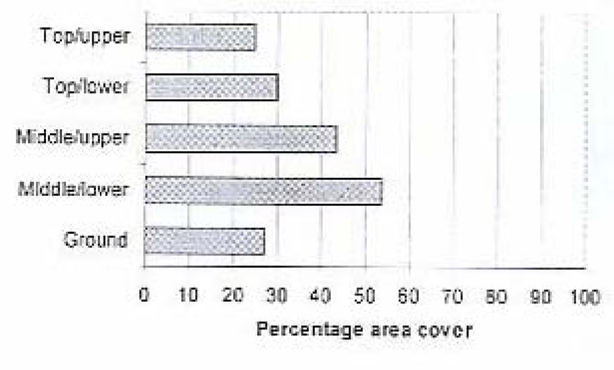


Diagram of the v lance and a conventional lanace configuration



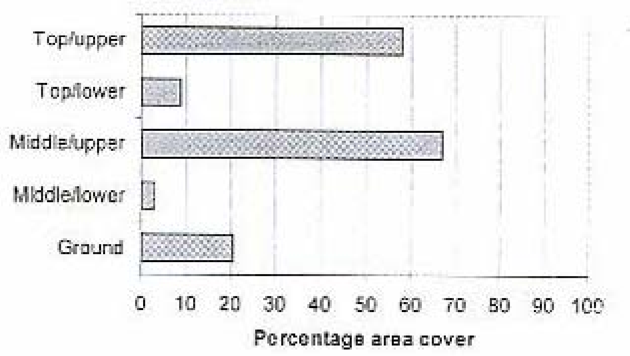
Getting the spray on target Most farmers hold the nozzle above the crop and spray downwards. Scientists from KARI (Kenya Agricultural Research Institute) together with CAB International (Centre for Applied Bioscience lnternational) and NRI (Natural Resources Institute) showed that this gives excellent spray coverage on the upper leaf surfaces but virtually none under-

neath on the lower side of the leaf. Some pests such as red spider mites, aphids and whitefly spend most of their time underneath leaves, and many diseases occur there too. Better underleaf cover can be achieved if the nozzle is held near the base of the crop being sprayed and pointed upwards into the crop. Some of the spray wilt land on the tower surface of the leaves, and the spray that misses the leaves on the way up wilt land on the upper surface of the leaves as it falls back down. The V lance (see inset) is an adaptation which allows the direction of the spray to be altered using a swivel adapter between the lance and the nozzle. The swivel allows the angle of the spray leaving the sprayer to be altered. When adjusted into the V position it is easy to spray upwards into crops such as kales, tomatoes and brinjals etc (see photo). Both spray distribution on the crop and pest control are improved compared with plants sprayed from above (see the figures which show that the spray

cover is much more even on both surfaces, using the V lance).

Farmers' tests

Sprayers fitted with V lances were given to ten smallholder vegetable farmers, along with finer spray nozzles, so that they could compare their existing equipment with that which had been modified. The V lance system was found to be suitable for tomatoes brinjals and french beans. One farmer wiped out his mite problem in a way which he said would have been impossible to achieve using a normal lance. However farmers found that v lances were less suitable for shorter crops such as cabbages. This indicates that a lance with a fixed angle would not be equally suitable for all crops. The ability to change from the 'v' configuration to a straighter more standard configuration is needed for shorter crops.



Some farmers were happy to nozzles which reduced the flow rate from 1.3 litres per minute, but the recommended 800 ml per minute was too low for some., who liked to see a heavy flow from the nozzle. As mentioned before, high flow rates above 800 ml per minute are often associated with unnecessarily high volume application rates, which can themselves be linked to over-dosing of the active ingredient.

Conclusions

The combination of drop size and spray placement is important to get the most benefit from any pesticide. Finer nozzles than those used by most farmers can improve spray effectiveness. For controlling pests and diseases in tatter crops the v lance gives good underleaf coverage of spray.

Spray coverage on tomatoes using a conventional lance (left) and a v lance (right) showing the more even coverage and better underleaf cover produced by the v lance. Top refers to the top part of the plant, and upper to the upper leaf surface.

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