CROP PROTECTION PROGRAMME

Environmentally acceptable crop protection strategies based on the improved use of pesticides and adoption of integrated pest management strategies by smallholder farmers in Zimbabwe

R6764 (ZA0054)

FINAL TECHNICAL REPORT

1 April 1997 - 31 March 2001

Project Leader: Hans Dobson

Natural Resources Institute

Executive summary

This collaborative research project was funded by the British Government's Department for International Development (DFID) through the Crop Protection Programme (CPP). It was implemented by the Natural Resources Institute (University of Greenwich, UK) and the Plant Protection Research Institute (PPRI, an institute of the Department for Research and Specialist Services [DR&SS]), Harare. The project arose as a result of demand in sub-Saharan Africa for safer and more sustainable vegetable pest management in this increasingly important commodity sector, hence the working title Vegetable Pest Management (VPM). The aim of the project was to develop crop protection methods for smallholders that integrate the beneficial effects of natural enemies with cultural practices and judicious use of pesticides.

As well as providing nutritious food to supplement the staple grain crops, smallholder horticultural production is an important and expanding component of rural livelihoods in Zimbabwe. Vegetable production provides employment and income for farmers, their families and employees in regions where unemployment levels are high. With HIV incidence currently between 20 and 33% of the population, and many female- and child-headed households, the nutritional benefits, coupled with the relatively rapid yields and revenues from vegetables are particularly important. Pest and disease damage threatens the magnitude and reliability of the harvest, and vegetable farmers' usual response is heavy and frequent application of synthetic pesticides. These are expensive but often only partially successful in protecting the crops. Reliance on pesticides has led to increasing concern about residues in produce, operator safety, pesticide resistance and environmental damage. Few alternatives are currently in use.

The project developed recommendations for improved pest management in several key areas. An important component was studying how farmers could use existing vegetable varieties to best effect. Some tomato varieties showed slight resistance to important blight diseases, but spraying continues to be necessary during much of the year. Root knot nematodes are tiny soil organisms whose insidious effects are often unnoticed or not attributed to the causal organism by farmers – measures to control them are rarely taken. Resistance of different crop varieties to nematodes was compared to produce recommendations for farmers on appropriate cultivars. Another central aim was to improve the way pesticides are applied in order to maximise their impact on pests. In collaboration with a linked project in Kenya, equipment and techniques were developed which give better-targeted spray distribution and under-leaf cover in particular. This equipment, whose success was reported in the scientific press (Sibanda *et al*., 2000), was also highly rated by farmers, particularly for crops such as brinjals, brassicas and tomatoes, and its biological efficacy against red spider mite pests was proven. A handbook and posters on pest management in brassica and tomato crops were produced, giving practical advice on pest and disease identification and control, using an accessible style and layout that will be useful to extension personnel, other agricultural trainers and progressive farmers. Throughout the project, the pest and disease constraints, trial plans and results of research work were discussed with farmers and other stakeholders so that the project could address their needs and the DFID development goal, namely '*productivity increased in smallholder high potential production systems by reducing losses due to pests*'.

Acronyms

AfFOResT	African Farmers' Organic Research and Training
AGRITEX	Agricultural Technical and Extension Service
CPHP	Crop Post Harvest Programme
CPP	Crop Protection Programme
DBM	Diamondback moth
DFID	Department for International Development
DRSS	Department of Research and Specialist Services
FAO	Food and Agriculture Organization of the United Nations
GoZ	Government of Zimbabwe
IPM	Integrated Pest Management
IPPM	Integrated Production and Pest Management
KARI	Kenya Agricultural Research Institute
NE	Natural Enemy
NGO	Non Governmental Organisation
NRI	Natural Resources Institute
NRIL	Natural Resources International Limited
PLENUM	Participatory Ecological Land Use Management
PPE	Personal Protective Equipment
PPRI	Plant Protection Research Institute
RKN	Root Knot Nematode
RSM	Red Spider Mite
VAR	Volume Application Rate
VPM	Vegetable Pest Management

Background

The *Purpose* of the High Potential Production System is 'yields improved and sustainability enhanced by cost effective reduction in losses due to pests'. The indicative output addressed by this project was 'environmentally acceptable herbicides, fungicides and bactericides, and agrochemical use systems, for application by smallholders and estate workers, promoted and adopted'. Areas falling under this production system are usually characterised by intensive land use, with copious use of pesticides to protect high value crops such as vegetables. This project was one of a number commissioned by the Crop Protection Programme (CPP) from 1996 to target output 1.14 of the Production System. The need to manage pests more effectively through safer and more judicious use of pesticides, as well as enhancing natural regulatory systems is implicit in any project contributing to this purpose.

The expanding urban population in Zimbabwe is increasing pressure on production in high potential and peri-urban production systems. Agriculture is the mainstay of the country's economy and is likely to remain so for the foreseeable future. Vegetable production is an increasingly important sector of agriculture, providing livelihoods for many thousands of families and the workers whom they employ. Although production has increased tremendously since the country became independent in 1980, and arable cultivation has been increasing, yields of crops per unit area have been decreasing (Chikwenhere and Sithole, 1993). In addition to problems of drought and water supply, production of all crops is constrained by a range of pests, diseases, and weeds that reduce both the level and reliability of yields. Dr Sithole, Head of Plant Protection Research Institute (PPRI) in the Zimbabwe Department of Research and Specialist Services (DRSS), identified several researchable constraints (Sithole and Chikwenhere, 1995) which would benefit from support in Zimbabwe, and which directly matched the CPP High Potential production system Goal. Among the most important of these were cutworms and diamondback moth on cabbages, nematodes, late blight and *Helicoverpa armigera* on tomatoes, fruit flies, white fly, aphids, nematodes on cucurbits and thrips and various diseases on onions.

Pest management methods used on high value crops in Zimbabwe are heavily dependent on pesticides. Their use is often inefficient, inappropriate, and in many cases, ineffective. Wilkinson (1993) stated that good spraying techniques are crucial in enabling the number of applications and doses to be reduced.

A significant factor that has increased the need for agricultural research support in Zimbabwe is the shift of production from large-scale to smaller-scale farms in areas more remote from agricultural support. This is illustrated well by the cotton crop that in the early 1980s was largely grown by large-scale commercial farmers who produced over 60% of the crop. By 1992, small-scale farmers accounted for 63.4% of the total cotton crop, with large-scale farmers making up the remaining 36.6%. (Jowah and Mubvuta, 1993). At the time of the Phase 1 proposal, PPRI were seeking to reform pest management by improving the way pesticides were used. They recognised that chemical control will continue to be the mainstay of crop protection at most levels of production for the foreseeable future, but that improved and optimised pesticide techniques and strategies, integrated with other biologically-based technologies, are required.

Zimbabwean vegetable farmers form a continuum from very large-scale commercial growers to the huge number of households who grow crops for their own consumption. This project was aimed at the smaller-scale end of the spectrum, and specifically at the vegetable farmers who produce a little more than their domestic needs and sell surpluses to local urban markets. They suffer significantly from lack of information and guidance to make their production more safe and efficient. The project made efforts not to exclude the other groups, some of whom would currently (or could in the near future) benefit from safer and more effective integrated pest management strategies. There was also the likelihood that knowledge transfer could be facilitated between farmers at the different scales of production e.g. useful indigenous knowledge on botanical products from smallholders to large producers, and biocontrol methods from large-scale organic producers to smallholders.

IPM implementation has been limited so far in Zimbabwe. There was and still is no national institution responsible for formulating and carrying out IPM policies and most of the IPM programmes carried out so far have been ad hoc. Chikwenhere and Sithole (1993) identified the urgent need for collaboration between government agencies, the private sector and research bodies to promote the use of alternative and improved pest management technologies, and Wilkinson (1993) reiterated the need for external assistance. Most smallholder farmers currently operate in a resource-poor environment. In Zimbabwe, reliable agronomic information relating to cultivar and seed choice, soil fertility, water management and pest management using cultural, biological and chemical methods is lacking (Sithole and Chikwenhere, 1995a).
It was perceived that the major short-term benefits would come from improved use of selected pesticides applied in a manner that is safe to the user, the consumer, and the environment. The long-term strategy was to reduce reliance on pesticides by adopting a mixed strategy of chemical and biological methodologies, including host plant resistance and cultural methods which enhance plant resistance and conserve and augment natural enemies of crop pests.

With the long dry season, many small-scale vegetable growers depend on wells for water supplies, but some are located on small irrigation schemes. Where there is a large concentration of growers within one area with good access to transport, some farmers also supply vegetables for export, through out-reach contracts with the major export companies such as Hortico. These export farmers receive support and inputs from the exporting companies, but this is certainly not the case for the farmer producing for the local markets who has little access to assistance or impartial advice on best crop protection practice.

For the local market, small-scale farmers grow a range of fresh crops, notably covo (*Brassica oleracea*), rape (*B.napus*), tomatoes (*Lycopersicon esculentum*) and green beans (*Phaseolus vulgaris).* Other important crops include cucurbits, peppers and onions. The average size of vegetable farms is 0.3 ha in Chinamhora, near Harare (Sibhensana, 1996), so rotation of crops is necessarily limited. Major problems limiting tomato production include root knot nematodes and late and early blight, but insect pests, notably aphids and the diamondback moth, are the main problem in brassica crops. Growers react by using pesticides, sometimes as frequently as twice weekly, using small sprayers and sometimes brooms to splash the product on. Poor pesticide application is a major constraint to good pest management, as is the lack of information on safe, efficient and sustainable alternative crop protection practices for these small-scale commercial vegetable growers. It was this challenge that led to the formulation of the Zimbabwe Vegetable Pest Management Project, which is the only one in Zimbabwe addressing the full range of smallholder vegetable pest management problems. As well as serving the needs of Zimbabwean farmers, it was intended that the work be of regional relevance and that there would be synergy between this project and others such as the CPP Peri-Urban project in Kenya - 'Pest Management in Horticultural Crops', hence the series of exchange study tours between the two countries.

Project Purpose

The RNRRS Programme Purpose '*Yields improved and sustainability enhanced by cost-effective reduction in losses due to pests* is being addressed through a Project Goal as follows: *Productivity increased in smallholder high potential production systems by reducing losses due to pests*. As defined in the Project Memorandum the Project Purpose is: '*To improve the long-term sustainability of pest management in smallholder high potential systems by improving the way pesticides are used, by identifying potentially useful natural control organisms and production systems, and by optimising the combination of pest control methods'.*

The project aimed to address:

- sporadic devastating crop losses due to pest upsurges as well as chronic low-level losses;
- limited understanding by small-scale farmers of conventional and alternative crop protection products, practices and strategies;
- over-dependence on and misuse of pesticides;
- poor access to good extension advice;
- financial constraints imposed by expensive inputs;
- loss of local and export revenue due to low yields of poor quality produce which sometimes has pesticide residues above acceptable levels.

There was and still remains clear evidence of demand for the original project. PPRI has a research priority to reduce pesticide use and promote IPM technologies and strongly supported the development of the original proposal. The urban population is expanding rapidly and the land reform programme coupled with the liberalisation of farming systems is likely to result in more smallholder farming of the more fertile land (often by relatively inexperienced farmers), most of which is still currently under large-scale commercial production. There is increasing access to irrigation, the expense of which is justified by, but also depends on, the high value of cash crops such as vegetables. Such cash cropping is also encouraged at a policy level due to the employment it creates at busy times of year.

Research Activities

Collaborator commitment developed over the first few months until, at the end of the first year, a very productive in-country team spirit had developed. Staff changes caused some delays (see staffing table in Appendix 1) while new local project leaders found their feet in their new posts. Retention of competent and motivated staff in Government service is a continuing problem due to low wages in comparison with the commercial sector or international posts. Project identity and productivity was enhanced by recruitment of a full-time research assistant who acted as pivot and provided much-needed continuity. Strong relationships have been built up over the course of the four years between all of the project players - farmers, extension agents, PPRI Director and staff, NRI and Kenyan staff from CABI and KARI. This has provided an environment in which much productive work has been carried out, requiring great initiative and self-motivation on the part of the Zimbabwean scientists who undertook the bulk of the project work.

Over the course of the four years, the project undertook numerous surveys, monitoring operations, field evaluations, formal trials, workshops, farmer meetings and study tours. These are described below using the headings for outputs and activities from the Project Memorandum, and Appendix 2 shows a summarised list of the formal trials carried out.

1.1 A survey in collaboration with PPRI staff of farming practices and production constraints in two selected areas.

An initial 20 week baseline survey was carried out to set the priorities for the subsequent research work.

A preliminary site selection survey was conducted by project scientists in Chinamhora, Mutoko and Sanyati. The criteria for selection were:

- accessibility - can be reached by vehicle in all seasons;
- proximity to Harare - can be visited in a day;
- contrasting agro-ecological zones - perhaps different altitudes;
- horticultural crop production - extensive vegetable production in the area.

Sanyati area was dropped because it was too far from Harare and there is also very little horticultural production. The baseline survey was therefore carried out at 2 sites: Mutoko (Natural Region 4) around 150 km east of Harare and Chinamhora (Natural Region 2) around 35 km north of Harare. For more detail, see report by Dobson and Sibanda, 1997.

Once sites had been selected, selection of farmers was done in collaboration with the Agricultural Technical and Extension Services (AGRITEX). A total of 6 farmers were selected at each site. However, in both sites work with one farmer was discontinued due to their inaccessibility. The farmer selection criteria were:

- accessibility from the main road in all seasons;
- farmer cooperation - willingness to participate in surveys and on-farm trials;

- level of production - producing vegetables commercially for sale in urban centres;
- crop range - a variety of different vegetable crops grown;
- access to irrigation water - allow continued production through the dry season.

During the baseline survey a minimum of 3 crops were sampled at each farm. The aim was to include a broad cross-section of crops so that the full range of pest and disease problems could be sampled. Crops were:

- Solanaceous plants - tomatoes, pepper
- Cucurbits - cucumbers, baby marrow, butter nut, squash
- Legumes - green and sugar beans
- Brassicas - rape, covo/kale, cabbage
- Onion-type - onions, shallots

Sampling interval at each farm was 2 weeks. Entomology and pathology assessments were carried out by sampling 10 plants randomly selected by throwing a stick in a diagonal transact across the field. The pests and diseases were identified and their severity assessed on a scale of 0-3 according to a set of criteria developed early in the project.

The Baseline Survey revealed the most widely grown crops and the pests and diseases that limit yield and quality. It also identified problems with the way pesticides are used. Summarised details are shown under the output section below, and full details are given in the Baseline Survey report (Dobson *et al*., 1997).

1.2 Laboratory and field measurement of spray application performance using current technology

A series of trials and investigations were carried out to assess the current practices and performance of spraying activities among project farmers. These included assessments of pesticides used, volumes and doses applied, application equipment and problems with it. All of these aspects were dealt with using questionnaires and data forms, either filled in by VPM staff during closely observed spraying events or by the farmers themselves.

In addition, site-specific measurements of pesticide deposits on crop plants were made as a benchmark for the process of developing technology and recommendations to improve the distribution of these deposits.

If a sprayer distributes spray well, it will achieve good biological effects (control of the pest or disease) provided the pesticide is appropriate to the problem and is applied at the right dose. Assessing spray deposition allows the standard of spraying to be measured without the need for an elaborate biological field trial, so it is quicker and less expensive to carry out. Different sprayers, settings, nozzles and techniques can be assessed and compared relatively simply and rapidly.

The spray sampling methods used in the project mainly relied on water-sensitive papers that change colour on contact with spray liquid. These papers can be purchased commercially [1] or prepared in the laboratory. They were distributed around the crop plants before spraying took place, being stapled to leaves at two positions on each plant. On taller plants such as tomato, these two positions were top and middle of the plant, whereas on shorter, more spreading plants such as cabbage, the two positions were edge and centre. The papers were folded before fixing them with a small stapler (size 10) around the edge of the leaves so that both upper and lower surfaces of the leaves were sampled. In addition to the sampling papers placed on the leaves, at the base of each plant a sampling paper was placed on the soil to determine how much spray reached the soil. Before and during spraying a data sheet was filled in, which noted the crop parameters and spray information such as flow rate, time spent spraying, type of crop, dose rate, and some meteorological parameters. After finishing the spraying, or when the measured spray assessment area had been treated, the volume used during spraying was found by measuring the amount remaining in the spray tank, and deducting this from the initial volume. Time spent spraying was used to verify the flow rate and calculate the volume application rate (VAR). After spraying, a few minutes were allowed for the spray to dry before gathering the papers and fixing them onto labelled backing sheets.

The sampling papers give a visual representation of spray distribution that can be used for a subjective assessment of sprayer performance or be used to show farmers or scientists the broad picture of the drop distribution within the crop. However to obtain quantitative data, the NRI Quantimet Q520 image analyser was used to analyse spray deposits on all papers. This device consists of a video camera to capture the image of the paper targets, and dedicated computer hardware and software to scan and analyse the image. It then calculates the parameters important in spray deposition, including percentage area covered by spray and droplet size and spectrum data. The most important parameter for our purposes was considered to be percentage area cover since this gives an idea of where the spray is going and how well it is covering the target.

Fifteen on-farm spraying operations were assessed in detail across the two sites on various crops and by various farmers. Further details are given in the Baseline Survey Report (Dobson *et al*., 1997) and results are discussed under Outputs.

1.3. Assessment of operator exposure to quantify risks and identify key safety improvements

Field trials were carried out at Chinamhora to assess exposure of operators to pesticides when spraying tomato and brassicas. Operators were given new protective over-suits and asked to spray normally. A fluorescent tracer had been added to the tank mix so that contamination could be detected under ultra violet light later on, while giving no immediate feedback to the sprayer operator. After spraying a known volume of spray over a known area of field, the suits were removed and taken for analysis by a photographic method developed at NRI (King and Dobson, 1992). This process was carried out for conventional and modified spraying equipment as described below.

---

[1] Available from Spraying Systems, Headley House, Headley Rd, Grayshott, Hindhead, Surrey GU26 6UH

1.4. Determination of persistence and residues of pesticides used currently on target crops

Pesticides applied to crops start to break down soon after application, and if left for the recommended time before harvest (the pre-harvest interval) should leave no residues to pose a risk to consumers, provided that the pesticide dose rate was correct. Two visits to Zimbabwe were made by an NRI specialist in residue analysis to assess the facilities in PPRI and to initiate some crop residue work. The general condition of the DRSS laboratories was found to be run-down and the unit was struggling to analyse accurately the major classes of pesticide (see report by Cox, 1998). The project assisted the capacity of the laboratory by provision of specialist training and some second-hand equipment. A small number of samples were analysed (see report by Nziromasanga, 1999), but the continuing shortcomings of the facilities and capabilities limited the number and value of the results from this activity.

1.5. Identification of natural enemies and pest mitigating crop management practices

During the baseline survey, observations were made on natural enemies. Limited ability to identify these natural enemies was a constraint in PPRI, but the situation improved after skill-sharing with Kenyan colleagues Dr George Oduor and Mr Peter Karanja during their study tours to Zimbabwe. Information was also gathered on non-pesticidal crop protection practices and farmers' perceptions of their efficacy - also presented in the baseline survey report.

It became clear that much work was required to raise the profile of natural enemies with farmers and extensions workers and a complementary CPP-funded short project (R7266) was later implemented using VPM project staff, infrastructure and project farmers. This is reported in detail elsewhere. Surveys for natural enemies were carried out on-farm by project staff supervised by Dr Robert Verkerk of Imperial College, and photographs taken where possible. A draft field guide and multi-lingual posters and flip cards were produced with assistance from NRI and in-country project staff and piloted at workshops in Kenya and Zimbabwe in 1999. Feedback was incorporated and final published versions are now available.

2.1 Identification of, and laboratory and field trials of, appropriate improved integrated strategies for key problem pests, and 2.2 (If appropriate) assess compatibility of chemical and natural control processes by quantifying the effect of commonly used pesticides on natural enemies

Integrating the various methods for controlling or suppressing pest and disease problems in ways that do not interfere with each other is the difficult balancing act faced by all inorganic farmers. The key is for farmers to use alternative methods such as rotations and resistant varieties wherever possible, and only resort to pesticides when all other prevention and control methods have failed. If and when pesticides are used, they need to be chosen carefully and applied in a judicious manner. The project set out to address these challenging aims by working with farmers, finding problem areas and researching solutions.

The quantification of pesticide effects on natural enemies is a complex task requiring trained staff and specialist facilities. It became clear that these did not exist at PPRI, but the topic was tackled by literature search under the separate natural enemy project and a table of effects of commonly used pesticides on key natural enemies was produced (Verkerk., 2001).

3.1 Development of new pest management guidelines for use in training and extension

Information on vegetable pest management was needed in a farmer-friendly and understandable format. A draft handbook of Integrated Vegetable Pest Management has been prepared and is undergoing field testing and peer review. The handbook deals with the two crops that account for around 75% of the cultivations – brassicas and tomatoes - and was keenly anticipated by a wide range of stakeholders. Two types of multilingual poster are also under development for use by agricultural trainers and farmers – see later for detail.

3.2 Workshop and field demonstrations of improved IPM approaches

Workshops, farmer meetings and demonstrations were an important feature of the project. They are more effective in convincing farmers than verbal recommendations, but also provide feedback on farmer needs and as such allow better targeting and fine-tuning of the research.

Table 1. Workshops and farmer meetings

Type	***Date***	***Location***	***Participants***
Farmer/extensionist workshop	13 May 1998	Murewa	42
Farmer/extensionist workshop	Nov 1999	Mutoko	43
Farmer/extensionist workshop	Nov1999	Chinamhora	48
Farmer exchange visit	28 July 1999	Mutoko	47
Farmer exchange visit	12 Oct 1999	Chinamhora	32
Extensionist/farmer workshop	13-15 March 2001	Murewa	34
Extensionist/farmer workshop	20-22 March 2001	Honde Valley	46
Extensionist/farmer workshop	27-29 March 2001	Bulawayo	45

The farmer exchange visits allowed open dialogue between the project farmers at the two sites and enabled farmers from each site to see the crops, pests and other problems found at others' sites.

The farmer/extensionist workshops provided the opportunity to present project findings to the farmers. A summarised Shona translation of the baseline survey report was distributed to all project farmers at the 1998 workshop. In addition, feedback was gathered on farmer priorities for the research – see section relating to this activity in outputs.

The three extensionist/farmer workshops in March 2001 served the two existing project areas, Mutoko and Chinamhora and two new areas, Honde Valley and

Bulawayo. Both of these new sites have expanding areas of smallholder vegetable production, which were characterised during socio-economic surveys in November 2000. They represent targets for dissemination of existing project findings and potential sites for any future research and dissemination activities.

These workshops served three purposes:

- To launch the publications from the Natural Enemy project (ZA0250) and disseminate key messages to as many extension staff (and subsequently farmers) as possible;
- To field test the draft Vegetable Pest Management handbook and posters and to identify extension staff and others who could provide constructive and critical feedback;
- To pilot methods and channels of dissemination for the IPM messages and to investigate options for future wider dissemination.

See page 36 for further detail on the dissemination workshops and materials.

Outputs

Output 1. Safer and more appropriate spray application technologies and methodologies for target crops

1.1 Evaluation of current pest management knowledge, practice and specific constraints in small-scale horticultural/cotton/sorghum/maize farming systems:

A baseline survey was carried out to characterise the detailed context for the project. This is described in the report by Dobson *et al*., 1997, which details major pests, diseases, natural enemies, sprayer types and pest management practices.

Table 2 below summarises the most important pests and diseases encountered during the baseline survey.

Table 2. Key pests and diseases in smallholder horticulture at Chinamhora and Mutoko

Crop	3 most abundant pests	3 most damaging diseases	3 most abundant nematodes
Baby marrow	Red spider mite Aphids Whitefly	Powdery mildew Virus	*Helicotylenchus* *Pratylenchus* spp *Cricoconemella* spp.
Butternut squash	Red spider mite Aphids	Powdery mildew	*Scutellonema*
Cucumber	Leafminer Aphid Whitefly	Powdery mildew Angular leaf spot	*Meloiogyne* spp. *Pratylenchus* spp.
Pumpkin	Whitefly Red spider mite	Powdery mildew Downy mildew	*Meloidogyne* spp.

	Leafminer		
Cabbage	Aphids DBM Helicoverpa	Blackrot	*Meloiogyne* spp. *Helicotylenchus* spp. *Tylenchus* spp.
Covo	Aphids DBM Whitefly	Blackrot	*Meloiogyne* spp. *Helicotylenchus* spp. *Tylenchus* spp.
Rape	DBM Aphids Whitefly	Bacteria?	*Meloiogyne* spp. *Helicotylenchus* spp. *Tylenchus* spp.
Onion	Thrips Red spider mite	Purple blotch White tip Tip die-back	*Helicotylenchus*
Shallot	none recorded	Tip die-back	none
Tomato	Red spider mite Aphids Leaf miner	Powdery mildew Alternaria Septoria	*Meloidogyne* spp. *Pratylenchyus* spp. *Scutellonema* spp.
Green pepper	Aphids Leafminer Whitefly	Bacterial spot	*Meloidogyne* spp. *Pratylenchus* spp.
Beans	Thrips Aphids Whitefly	Bacterial blight Virus Anthracnose	*Meloidogyne* spp. *Pratylenchus* spp.

These are not necessarily the pests/diseases to which the crops are most prone - if no crop protection measures were taking place, there might be others which would assume more importance. Those listed above are the ones which are not very well controlled by current pest management interventions and as such are the ones at which the project research was aimed.

Further detailed comparison and graphs tracking the pest numbers over the 20 week sampling period are given in the baseline study report, but conclusions are summarised below:

- Vegetables suffer attacks from many pests and diseases and some of these are not being controlled adequately by current pest management methods;
- Pesticide application can be improved in terms of product choice, thresholds for spraying, volume application rate, dose applied and getting the pesticide to where the pests are i.e. predominantly under the leaves;
- Operator safety is questionable with minimal use of personal protective clothing;
- Plant parasitic nematodes are a major constraint on production of some crops such as tomato, but are often not recognized as such because they are not seen by the farmer;
- Organic farming is not prevalent in the areas studied, nor are there many cultural or biological practices used to supplement the use of synthetic pesticides for crop protection;
- Perhaps due to the level of pesticide use, natural enemies do not seem to be very abundant or active in suppressing pest populations. However, this requires further investigation;

- Research is also required on issues such as better and safer control of the major pests and diseases, appropriate methods of nematode control and improved pesticide management and application;
- Other constraints on small-scale commercial vegetable producers include lack of access to extension advice, non-availability of appropriate and clean seed varieties, shortage of transport to market, scarcity of irrigation water at the end of the dry season.

1.2 Laboratory and field measurement of spray application performance using current technology

A series of trials and investigations were carried out to assess the current practices and performance of spraying activities among project farmers. Some of these are detailed in the baseline survey report and a report presented at the XIVth International Plant Protection Congress (IPPC) – Jerusalem, Israel: 25 – 30 July 1999 and published recently in Crop Protection (Sibanda *et al.*, 2000).

In summary, the project found that there were major shortcomings with spray application: tank concentrations were usually lower than recommended (from 20% up to 100% of recommended) with farmers having the perception that he/she was eking out the expensive concentrated product – see Figure 1.

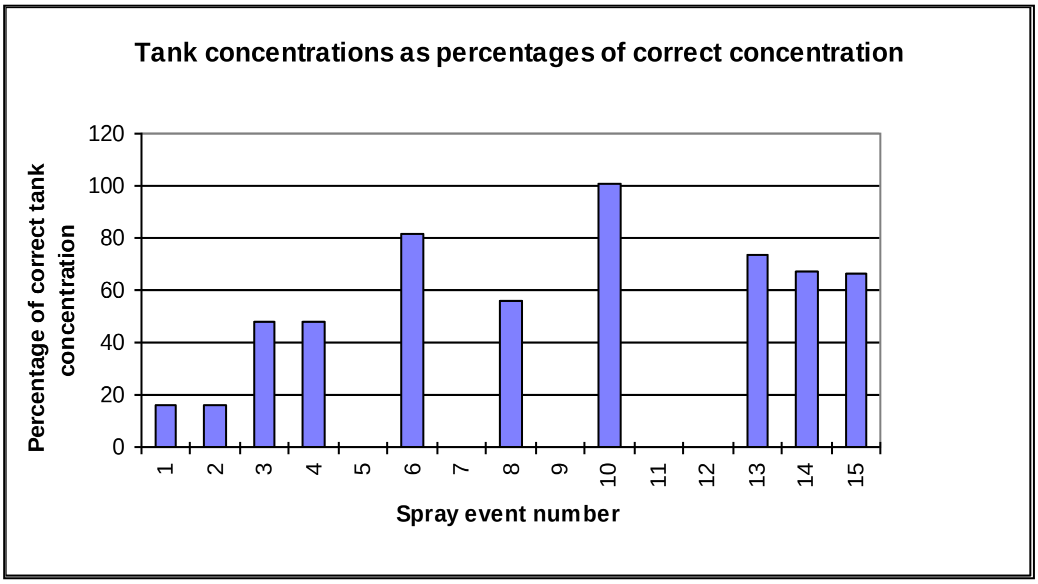

Figure 1. Tank concentration as a percentage of recommended concentration observed at 15 spray events on VPM project farms.
(Note: missing bars are where label does not state a recommended VAR).

However, volume application rates (the amount of diluted spray applied to the crop) were very variable. In some instances, they were excessively high - up to 600% of recommended volumes due to unwise use of large, worn or damaged nozzles – see Figure 2.

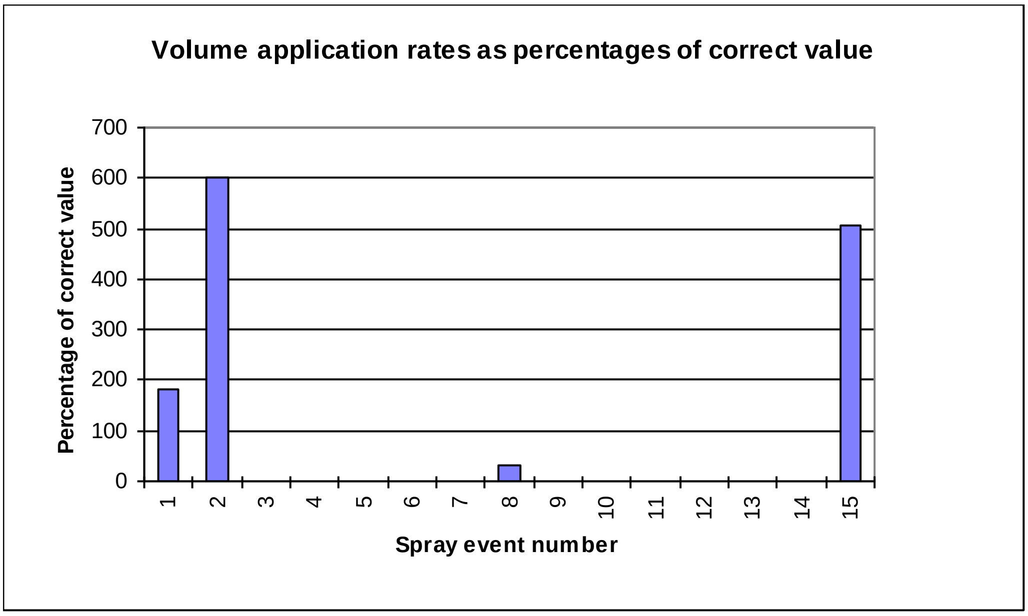

Figure 2. Volume application rates as a percentage of correct value observed at 15 spray events on VPM project farms
(Note: missing bars are where label does not state a recommended VAR).

The result of a combination of low tank concentration and high volume application rates is highly variable dosing ranging from 5 times the recommended dose down to a small fraction of it - see Figure 3.

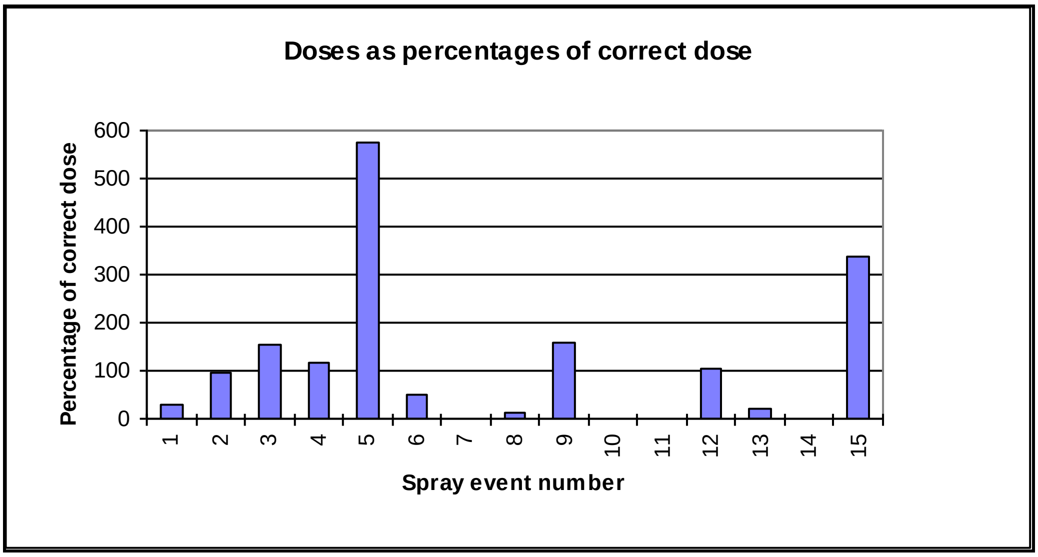

Figure 3. Doses as a percentage of correct value observed at 15 spray events on VPM project farms
(Note: missing bars are where label does not state a recommended VAR).

1.3 Field assessment of operator exposure when applying pesticides to identify and quantify risks.

A general findings during the baseline survey and subsequent field observations was that personal protective equipment (PPE) was rarely worn. For low to moderately toxic water-based products, it is recommended by FAO and GIFAP (FAO, 1990 and GIFAP, 1991) that a cotton coverall and foot protection be worn for application and that during mixing of the concentrate, gloves, a face shield and protective apron be worn. For more toxic products and for taller crops, gloves are recommended during application. It should also be recognized that pesticides can only be used safely, even with appropriate PPE, if the operator adopts certain practices to avoid exposure e.g. not eating, drinking or smoking during handling and application, not blowing blocked nozzles with the mouth and always staying upwind of the spray. Some of these practices were noted during the many observed spray events, as were other factors likely to represent health hazards such as inappropriate pesticide choices (monocrotophos in one instance) and hardware defects such as leaking sprayers (50% of sprayers sampled).

Some of these factors indicate the need for awareness-raising about pesticide hazards and comprehensive training in pesticide management and application. As a precursor step in this process, an attempt was made to assess the relative levels of contamination between spraying with conventional lances and with the modified V lance on brassicas and tomato. As described earlier, exposed suits were taken to NRI for analysis using a photographic image analysis technique.

Examination of the photographs revealed that both methods caused some contamination especially on the lower leg, probably partly as a result of rubbing against sprayed vegetation while moving through the crop. However, there was no indication that the V lance produced more contamination than the conventional lance. There was also evidence that this routine low-level secondary contamination was overshadowed occasionally by heavy contamination on the operators back as a result of leaking or overflowing sprayers. This and other sources of contamination such as pouring of concentrate without gloves is likely to represent a much greater hazard than any contamination during spraying itself.

1.4 Field determination of the persistence (residues) of pesticides currently in common use on the target crops

No residues above the maximum residue limits (MRL) were detected, but this data should be treated with caution - it was only a very small sample and the sensitivity of some of the analysis equipment in PPRI was still low and variable despite the efforts by an NRI specialist to upgrade it. In an attempt to verify the results, a few samples were sent for analysis at commercial rates to the residue laboratories at the Tobacco Research Board. These also did not pick up excessive residues but the samples could not be checked for the full range of pesticides due to some of their equipment also being out of service. For more details, see report by Nziramasanga, 1999.

Further work in this area is urgently needed to explore the relationship between spray applications and residues on crops. It will also be necessary to study residues in produce on market stalls. Incidents such as harvesting on the same day as spraying (long before the recommended pre-harvest interval) and heavy over-dosing have been observed and could pose a health hazard to consumers.

1.5 Identification of key natural enemies and pest-mitigating crop management practices

Despite some general conceptual awareness of natural enemies, farmers' initial ability to identify them, or even to discriminate between them and pests, was very limited. There was enthusiastic demand for production and distribution of the finished version of the natural enemy field guide and other printed materials (now available).

Output 2. Integrated pest management solutions for major pests of target crops

2.1 Identification of, and laboratory and field trials of, appropriate improved integrated strategies for key problem pests

The key problem pests and diseases were identified during the baseline survey and subsequent efforts focused on the following problems:

- red spider mite on tomato, and diamondback moth and aphids on brassicas;
- root knot nematode of various vegetables including tomato and beans;
- early and late blight on tomato.

Red spider mite (RSM – Tetranychus evansii) and other under-leaf pests

Farmers often complained of the difficulty of controlling red spider mite on tomato. It was not clear whether the poor control is due to build-up of resistance in the mites to the pesticides being used, or whether the pesticide is simply not reaching these particularly difficult under-leaf targets with their partially protective web. Screening for resistance was considered beyond the scope of the current project so the theory that poor application was at least partially responsible was tested. Trials were set up in 1998 at Henderson Research Station near Harare in March to compare control of these and other pests and diseases using conventional sprayers with control by modified equipment likely to give a better underleaf cover.

The deposition from a conventional lance was assessed on rape and tomato at Henderson Research Station. Ten plants were selected at random in 5 x 4 m plots of rape (30 cm high) and tomato (70 cm high) and water-sensitive papers were deployed as described earlier. A sprayer operator was asked to spray the plots with Rogor 40% EC (dimethoate) using a Taurus lever-operated knapsack sprayer. After drying, the papers were collected and analysed using the NRI Quantimet image analyser with respect to percentage area cover and the means data from the ten plants of each type are presented in Figure 5.

A modified lance known as the 'V lance' (developed together with a separate CPP-funded research project in Kenya was tested to see whether this could improve the uniformity of deposition on upper and lower leaf surfaces. The V lance is a simple adaptation of a conventional lance with a brass swivel joint inserted between the lance tube and the nozzle assembly. This allows the nozzle angle to be adjusted to direct the spray upwards rather than downwards – see Figure 4.

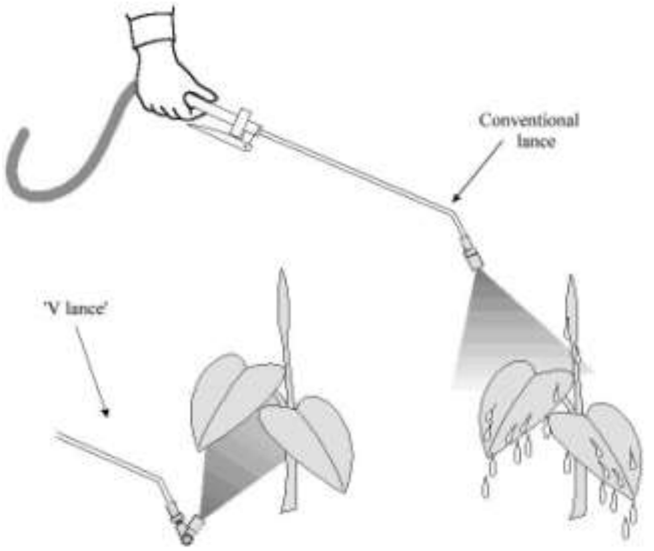

Fig 4. Spray directions from a conventional lance and a ‘V lance’

Water-sensitive papers were deployed again on similar plots adjacent to the previous plots at Henderson Research Station and the operator was asked to spray them using the same sprayer, pesticide and nozzle, but with the V lance fitted. A slightly different technique was required involving keeping the spray nozzle lower so that the spray was directed upwards at the leaves rather than downwards. Papers were removed and analysed in the same way and the means of the ten, percentage area cover measurements are presented in Figure 6.

a) Rape b) Tomato

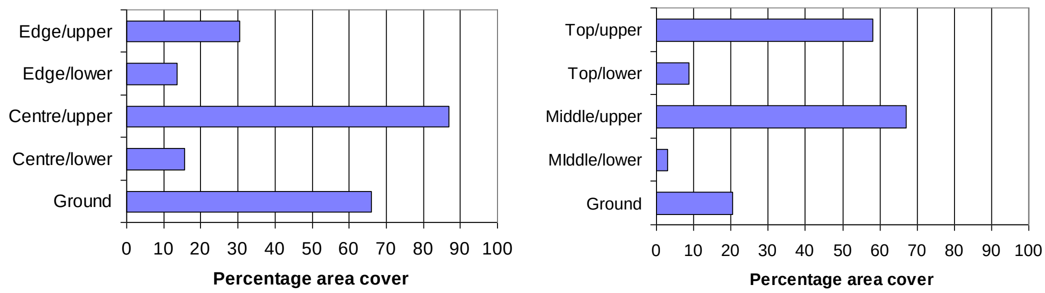

Fig 5. Percentage area cover of the spray from a conventional lance on different zones of rape and tomato plants

The data shows that the conventional lance produces deposit areas on upper leaf surfaces between 60% and 85%, but under the leaves, it is less than 15% for the rape and less than 10% for the tomato. Percentage area cover of the ground underneath the rape and tomato plants is around 65% and 20% respectively.

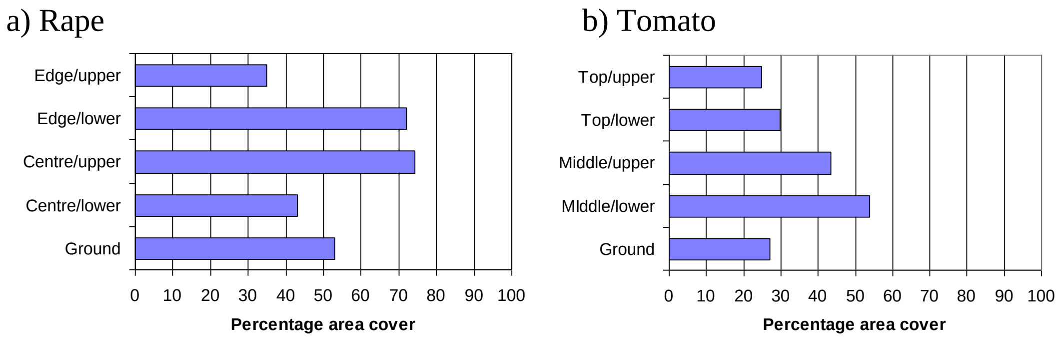

Fig 6. Percentage area cover of the spray from the V lance on different zones of rape and tomato plants

Visual impressions of the V lance spraying process indicate that some of the spray droplets are deposited on the underside of leaves on their way up and those that miss the leaves deposit on the upper leaf surface as they fall back down. This is corroborated by the data (see Figure 6) which show that, although deposition still varies on different parts of the plant, overall it is much more uniform than with the conventional lance. Minimum deposit cover under the leaves has been increased on the rape from 15% to around 35% and on tomato from less than 5% up to 25%. Maximum deposit cover has been decreased somewhat due to the re-allocation of the pesticide from upper to lower leaf surface – upper leaf cover has been reduced from 85% to 75% on rape and from 65% down to 55% on tomato.

These results have great significance for the efficacy of spray operations since many of the serious vegetable insect pests spend much of their time on the underside of leaves. It may also be significant for control of plant diseases where underleaf infection (through splashing or other transmission mechanism) is important.

Following this technical performance assessment, the V lances were distributed to project farmers for them to evaluate durability and practicability. Feedback was very positive with some farmers reporting that they were able to reduce doses and frequencies of application, particularly for red spider mite control – see later for more details on farmer perceptions and reactions.

Conclusive biological efficacy data was elusive. After the first few pest scorings at Henderson Research Station, both tomato and rape trials were destroyed by unseasonal frost. The tomato trial was replanted but infection by blight killed the crop before meaningful biological data had been gathered. A third attempt was made but despite efforts to introduce them, red spider mites were not sufficiently abundant to compare different treatments.

Finally the efficacy comparison was transferred to the glasshouse, where, after several failed attempts, mites were successfully introduced to a tomato crop and multiplied rapidly. Three replicates were carried out of three treatments – Dicofol sprayed through a conventional lance, Dicofol at the same dose through a V lance and a control treatment consisting of water sprayed at the same volume application rate as the other treatments. The replicates within the trial were arranged as rows (of 11 plants) in order to be able to spray at a steady speed and achieve uniformity of volume and dose, but the treatments rows were configured randomly within the block. Deposition data bore out the field findings that the V lance improved underleaf cover – see Figures 7 and 8.

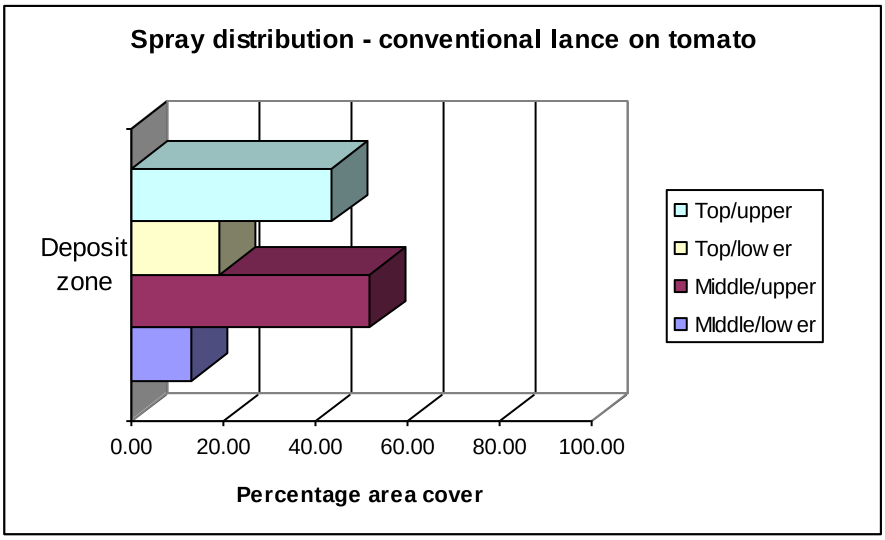

Figure 7. Deposition on different parts of a tomato crop when using a conventional spray lance

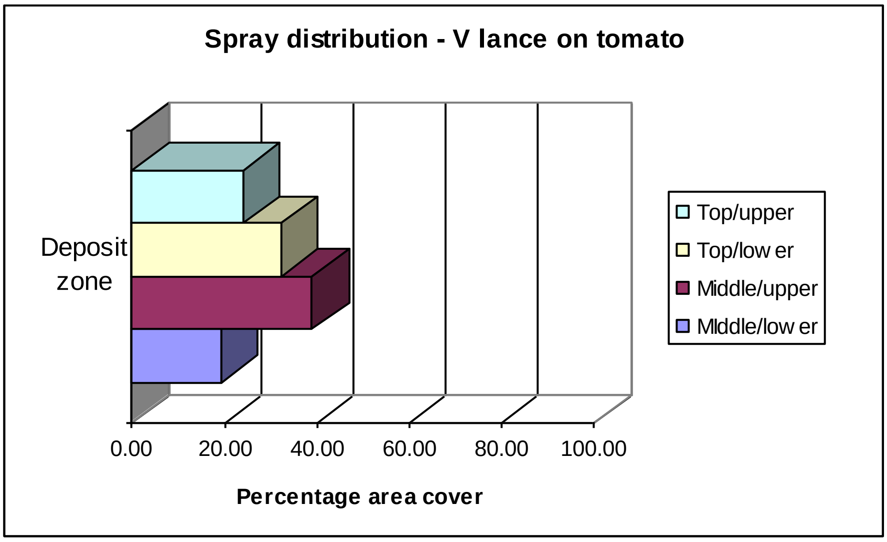

Figure 8. Deposition on different parts of a tomato crop when using the V lance.

Red spider mite numbers were monitored over the course of 17 days, during which time two spray applications were carried out – on 10 and 20 April. Leaf samples were taken from each water-sensitive paper site. Each leaf was placed in a labelled envelope which was stored in a fridge counted to slow down the mites and keep them on the leaves before being counted. Figure 9 shows the population trends for the three treatments over time.

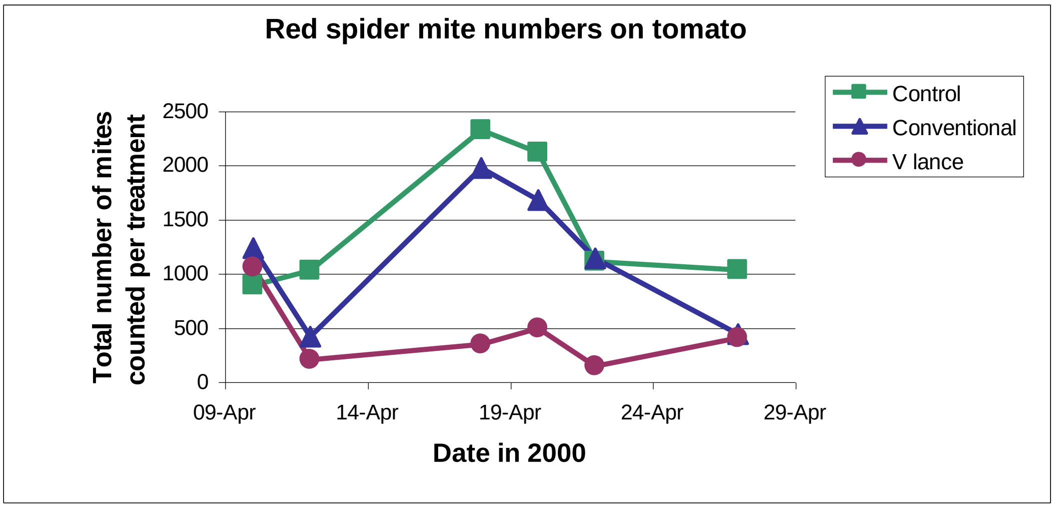

Figure 9. Red spider mite numbers on tomato when sprayed with water (control) and with dicofol using a standard lance (conventional) and an improved lance (V lance).

RSM numbers dropped in the conventional and V lance treatments after the first spray event, but subsequently rapidly increased in the former to close to the levels in the control treatment. After 20 April, the crop began to senesce and RSM numbers decreased in the control and the conventional treatments, but were still over three times the number in the V lance treatment until close to the end of the trial.

When total numbers of RSM counted over the course of the trial are considered, the differences are equally clear as shown in Figure 10.

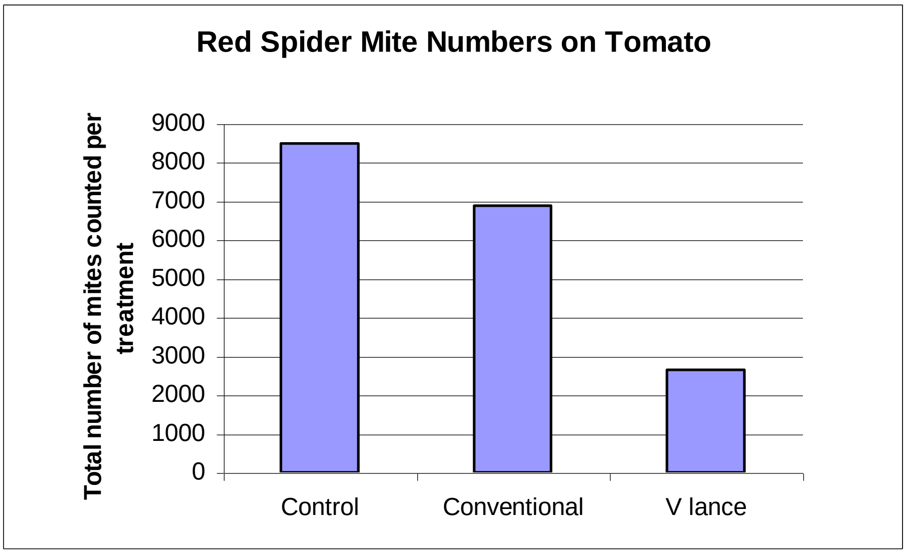

Figure 10. Number of mites on plants sprayed with water (control) and plants sprayed with dicofol using a standard lance (conventional) and an improved lance (V lance).

When analysed, these data show that control and conventional treatments are insignificantly different, but that the V lance numbers are highly significantly different from the control and conventional treatments.

It seems that much better control of RSM can be achieved by better targeting of a commonly-used product – suggesting that pesticide resistance is not solely (if at all) responsible for the poor control experienced by project farmers. The benefits of such better-targeted spray are either better pest control, or the opportunity to reduce dose/frequency of spraying, or both.

An attempt was made to repeat this glasshouse trial later in the season, but the process of artificial infestation of the tomato crop was unsuccessful before the crop began to senesce.

Two criticisms of the V lance emerged early on: spanners are needed (and may not be available) to alter the brass swivel angle; and if the joint is forced, leaks develop at the joints; secondly, the weight of the brass swivel at the end of the lance makes it more difficult to manoeuvre the nozzle quickly in and out of the crop canopy. Subsequently, a range of plastic and nylon swivel joints[2] have been examined which are much lighter and the angle of the joint can be altered by hand without the need for tools, but these were not introduced in time for all farmers to evaluate them.

A further refinement of the V lance was developed using a commercially available flexible aluminium lance extension – see Figure 11. This allows the possibility of adjusting the nozzle angle (to cope with small and large stature crops) without the need for spanners to loosen the brass swivel. Both types of modified lance were distributed to project farmers and feedback on their practicability and acceptability was gathered during project workshops in December 1999 and subsequent farm visits (see later).

[2] Available from Spraying Systems, Headley House, Headley Rd, Grayshott, Hindhead, Surrey GU26 6UH

Figure 11. The Flexi lance – a flexible lance extension that can be bent in any direction and will hold its position

With the aim of getting feedback on acceptability to farmers, five project farmers at Chinamhora and four at Mutoko were supplied with a brass V lance and a Flexi lance, together with adapters to fit them to their sprayers. They were asked to try them out during normal spraying operations with no obligation to keep using them after trying them out.

Several weeks later, follow-up visits were made to each farm to gather feedback using a standard form. Of the six farmers who felt able to judge, all six felt that pest control was better with one or other of the modified lances. One farmer claimed to have halved his spraying frequency against red spider mites. One farmer commented that the modified lances provided better disease control, another felt that disease control was the same and yet another reverted to his standard lance for fungicide treatments. Of the farmers who expressed a preference, 3 preferred the Flexi lance and 4 preferred the V lance.

Various useful additional comments were made. Three farmers commented that the brass V lance was too heavy and limited lance mobility in the crop, one commenting that this slowed his spraying down. At the time, only one plastic V lance was available and the farmer who tried it commented that its lighter weight made it better than the brass type. One farmer felt that spray droplets were smaller from the Flexi lance than from the V lance, although this should not have been the case since the same nozzles and swirl plates were meant to be used in both. The simple method of changing the spraying direction with the Flexi lance – bending the lance tip – was appreciated by one farmer. One farmer had not tried the modified lances since he felt his conventional lance was working well.

Table 3. Farmer feedback on the V lances and the Flexi lance

Farmer	Prefer*	Pests	Diseases	Some of the additional comments
Ngoshi	F	better		F lance is lighter
Bapata	F	better	same	F lance flexibility is good and lightness is good
Nyakudya	V/C			V lance used for pests, conventional for diseases
Nyakudya (2)	V	better	better	Plastic V lance is better than brass.
Mubitsi	V	better		Successfully using V lance since distributed
Mazarura	C			Not tried yet - conventional lance is working well
Nyawasha	F	better		Brass V lance too heavy so using F lance
Chipfupi	V	better		V lance is very useful

* F = V Flexi lance, V = V lance, C = conventional

Overall, most of the farmers felt positive enough about one or other of the modified lances to continue using them and to provide comments suggesting that they gave better pest control and/or reduced pesticide requirements. Confidence in the lances' performance against diseases was less clear cut, but this may be because spray efficacy on diseases is less easy to judge.

The diamondback moth (*Plutella xylostella)* is also a big problem at certain times of year on brassicas, as are various species of aphid. The difficulty of keeping these pests under control is again thought at least in part to be due to poor spray application, with the greatest proportion of spray from conventional equipment landing on the upper surface of the leaves while the pests shelter underneath. However, there may (as in Kenya) be build-up of resistance to pesticides and this is something requiring further work. However, it is likely that the V lance or Flexi lance technology will significantly improve control of these major pests of brassicas.

Root knot nematodes

Root knot nematodes (principally *Meloidogyne* spp.) are a less obvious, but no less serious problem. Farmers often mis-diagnose tomato crop failure due to heavy galling as disease attack or unexplained early senescence. The baseline survey showed that nematodes are a much more serious problem for the vegetable farmers in Zimbabwe than for their counterparts in Kenya. Control is problematic as soil sterilisation products are not cost effective. In addition, use of the hazardous sterilization products and techniques by smallholders is questionable on safety grounds. Some form of mechanical or cultural control method is likely to be more appropriate for smallholders. Rotation is a recommended practice to try to suppress nematode numbers – a susceptible crop such as tomato is followed by a less susceptible crop such as onions and vice versa. The NGO AfFOResT (African Farmers' Organic Research and Training) advocates the STRONG rotation system – an approximate acronym of Susceptible, Tolerant then Resistant, representing the sequence of crops to be planted. However, the principles of these rotations are not well understood or implemented by most farmers practising conventional agriculture, some of whom have too small a land holding to achieve an effective rotation.

AfFOResT also advocates the use of *Tagetes* spp as a nematode repellent crop and Sunnhemp as a nematode trap crop. N.B. Susceptible crops can be planted when the soil temperature is < 16 degrees centigrade since the nematodes are not active when the soil is cooler. Rigorous trials are required of these and other potential technologies to provide definitive data on their benefits and best implementation details.

Some varieties of tomato resist nematodes better than others e.g. Zest F1, but such varieties are not always available and there seem to be incentives for growing more susceptible varieties such as Money Maker because of the higher yields it can produce and the demands of the market.

There are also problems with the rotation recommendations - one of the crops usually thought to be resistant, i.e., onions, proved to be a reasonable host in the field trials. This indicates the need to assess alternative control techniques such as solarisation of the seedbeds before sowing using black plastic, or increasing the amount of organic matter in the soil, flooding it and/or desiccating it. Investigation of the relative merits of all of these practices was considered too large an exercise for this project, given that the Senior nematologist had departed to the Tobacco Research Board in 1997 and the very experienced senior technician took early retirement at short notice in 1999.

Trials were carried out to compare nematode susceptibility in 3 varieties of bean (sugar beans, green beans and exrico) and 2 varieties of onion (Savannah sweet and Texas Grano) – see report by Rangarira, 1999.

Figure 12 shows RKN numbers on the three bean types, each of which had a control plot treated with Nemacur. It is clear that green beans and Exrico beans have a much lower susceptibility to *Meloidogyne* spp RKN than sugar beans so the latter should be avoided in areas where nematodes are a problem.

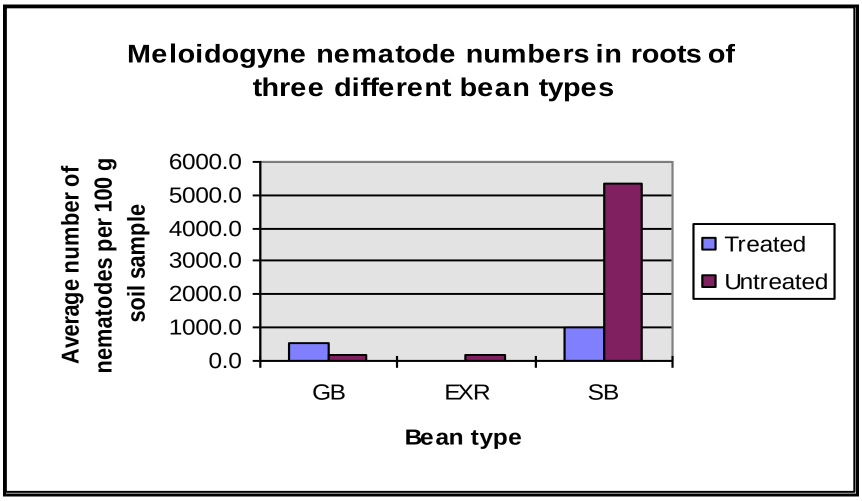

Figure 12. Root knot nematode numbers in the roots of three common varieties of bean
Key: GB=Green Beans; EXR= Exrico; SB= Sugar Beans.

The summarised results from the onion variety trial are shown in Figure 13

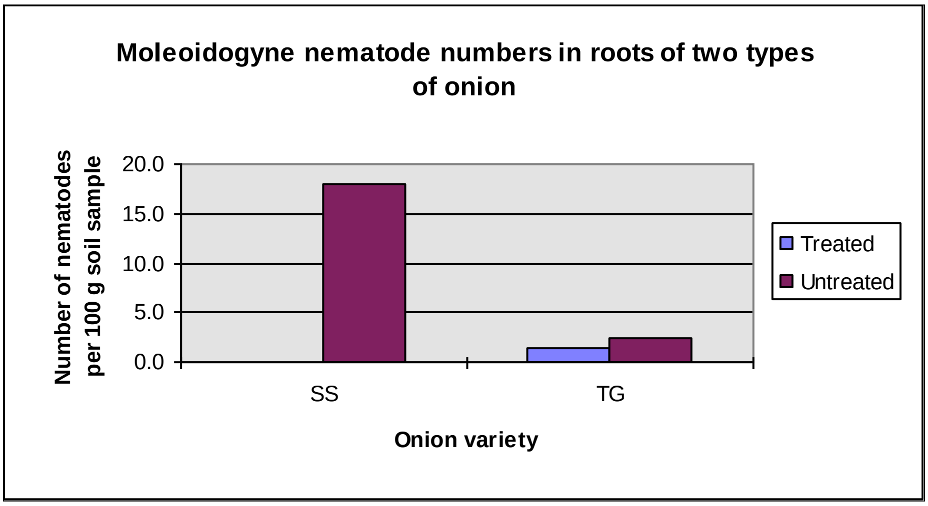

Figure 13. Root knot nematode numbers in the roots of two common onion varieties
Key: SS=Savannah sweet; TG=Texas Grano.

Results indicate that Texas Grano is less susceptible than Savannah Sweet and should be recommended in areas where nematode numbers are high.

Aphids

A trial to assess practical threshold levels for treatment of aphid infestations was carried out on kale at Henderson research station. Treatments were:

1. Aphid threshold score 0 (no aphids)
2. Aphid threshold score 1 (1-10 aphids per plant)
3. Aphid threshold score 2 (1-2 colonies developing/plant)
4. Aphid threshold score 3 (3-several colonies developing/plant)
5. Scheduled spraying at***** 2 weeks interval
6. Control no spraying

Treatment 6 was unsprayed, treatment 5 was calendar sprayed at two-week intervals with Malathion 50 E.C at the recommended rate and other plots were sprayed with the same product when they reached their aphid threshold. Weekly data was gathered on aphid abundance over a two month period together with yields (total and marketable) at each harvest. Unfortunately aphid levels were lower than desirable for the trial (and diminished over time) and it was found to be difficult to achieve the desired relative differences in the aphid populations between treatments – see Figures 14 and 15. Nevertheless, treatments 1 and 5 (zero tolerance to aphids and calendar spraying) appeared to achieve aphid population levels different from the other treatments.

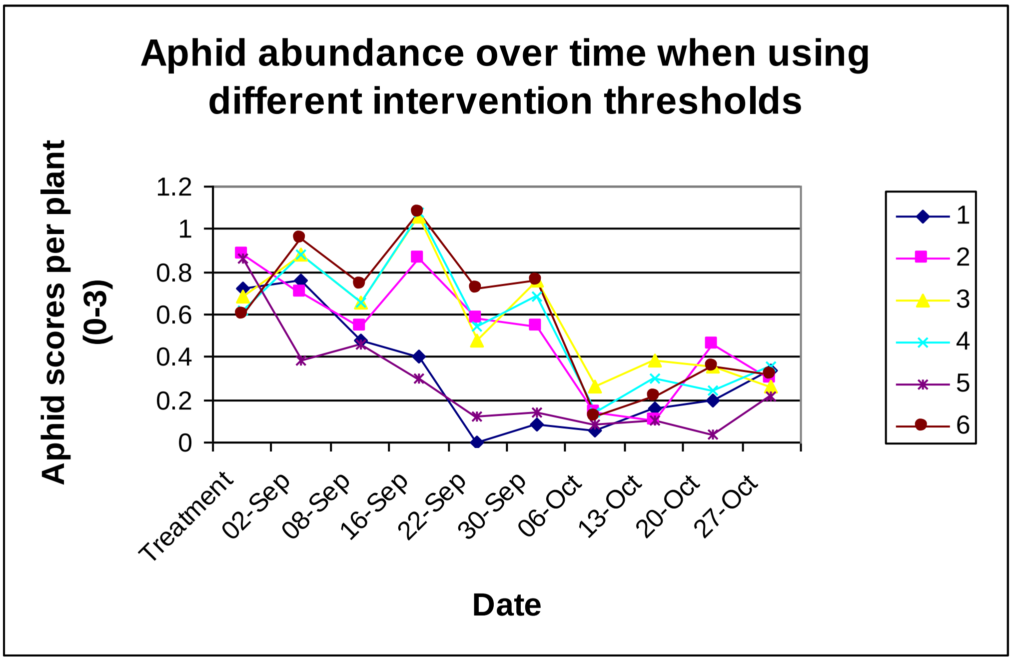

Figure 14. Aphid abundance over time using 6 different control strategies

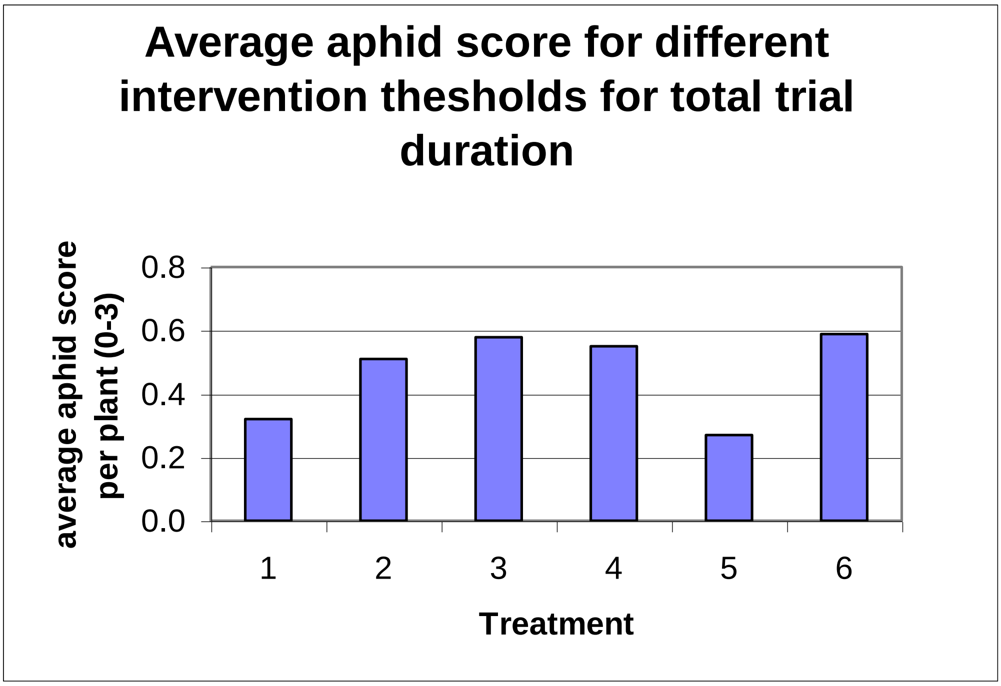

Figure 15. Average aphid score throughout the duration of the trial using 6 different control strategies

However, when total yields of marketable produce were examined, the differences between treatments were not significant – see Figure 16.

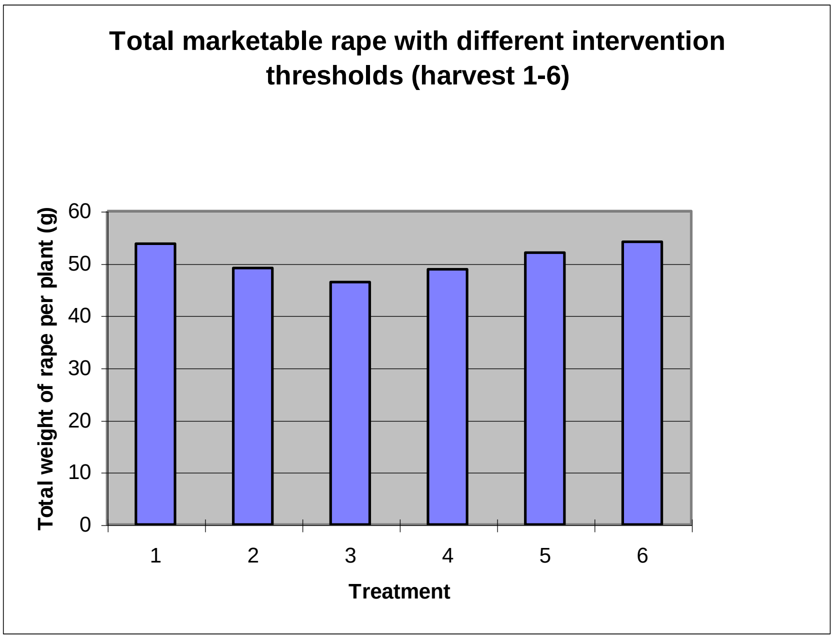

Figure 16. Total marketable yield of rape over the course of the trial using 6 different control strategies.

The yield from the untreated control treatment was difficult to explain – it appeared to produce as high a yield as any other treatment, despite the fact that aphid numbers were high relative to other treatments. It may be that although aphids cause little marketable yield loss at these low numbers, the lack of spraying encouraged parasitoids and predators of other damaging pests such as DBM. These confounded variables are a feature of field trials, even where trial design has attempted to isolate the variable of interest – in this case, aphids.

The significant conclusion from this trial is that aphids at such low numbers (average scores per plant of between 0.2 and 0.6) do not warrant control operations.

Diseases

While late blight (*Phytophthora infestans*) is an important disease of tomato under moist conditions in Zimbabwe, early blight (*Alternaria solani)* is often the more serious constraint to tomato production. This contrasts with Kenya where late blight is much more serious than early blight. Field trials were conducted at Henderson Research Station during the 1998/99 summer season to evaluate early blight tolerance in six tomato cultivars. The cultivars evaluated were Floradade, Heinz, Zest, Zeal, Roma and Moneymaker, which is indeterminate. An on-farm trial was also conducted at Mutoko to evaluate early blight incidence on ten tomato cultivars namely; Heinz, Lisheng brand, Golden Pear, Moneymaker, Rossol, Roma, Homestead, Pink king, Orient pearl and Red khaki. At Henderson, the cultivars Zest, Zeal and Floradade had no significant ($P< 0.05$) differences in both yield and the incidence of early blight. The cultivar Moneymaker had the highest incidence of early blight attack but it also had the highest yield ($P< 0.05$) although the fruit quality at the end of the season was poor.

Weeds surrounding the crops were screened for *Alternaria solani* infection at Henderson. Weeds found to be infected were *Amaranthus* sp., *Physalis angulata*, *Bidens pilosa* and *Nicandra physalodes*. No *Alternaria* was found on the grass weeds. The results show that although Moneymaker is a high yielding cultivar, the high incidence of early blight and the poor quality produce imply that it has to be grown under low early blight disease pressure. Under high disease pressure conditions, the cultivars Floradade, Zest and Zeal would be recommended as they yield moderate but good quality fruits. In Mutoko, the cultivar Rossol proved to be the best yielder and was also tolerant to early blight. As a bonus it was also tolerant of Red Spider Mites (*Tetranychus evansi*). See report by Manyangarirwa (1999a) for more details.

A further survey was carried out to identify diseases in tomato seeds used by the VPM farmers. It is apparent that neither the seed from the farmers nor seed from outlets such as A1 contain significant levels of seed-borne fungi. The conclusion is that much of the farm-saved vegetable seed is of high quality (as regards fungal disease burden) and if farmers can maintain such standards, there is no reason to discourage farmers from saving seed. It also implies that much of the disease causing inoculum is from airborne spores, soil-borne spores or spores from alternate hosts or plant debris so cultural practices that minimise these sources should be encouraged e.g. burning or burying crop trash and rotation regimes. Questions still remain over the extent to which seed is a transmission mechanism for one or two important bacterial diseases of brassicas and beans and one or two important viral diseases of beans and cucurbits. See report by Manyangarirwa (2001) for more details.

2.2 Assess compatibility of chemical and biological control technologies by quantifying the effect of commonly used pesticides on natural enemies

Natural enemies were looked at in the baseline survey, and found to be present, albeit in low numbers, despite use of often poorly calibrated pesticide sprays. However the necessary more thorough study was to a large extent covered in the collaborating project R7266, during which a literature search and review was carried out and a table compiled ranking pesticides in terms of severity of impact on various natural enemies (see separate project FTR of project R7266 and the field guide by Verkerk, 2001).

Output 3. Dissemination of safer pest management methods in line with Zimbabwe's policy for integrated pest management

3.1 Development of new pest management guidelines for use in training and extension

Results from field trials, surveys and farmer discussions, supplemented by appropriate information from other sources were used to produce a handbook for pest management in the two most important crops – brassicas and tomatoes. The handbook also contains information on specific issues such as sprayer maintenance, calibration, nurturing natural enemies, soil health, pesticide safety (in collaboration with the agrochemical industry). Two draft posters have also been developed for use by extension staff, NGO agricultural trainers and farmers.

During workshops and discussions it was apparent that the support and advice provided by the project has been welcomed by all stakeholders. So far the proportion of effort on research has outweighed that on dissemination. The opportunity exists to scale-up and disseminate much more widely through the extension service, AGRITEX, with which the project has good links, and through organisations such as PELUM (Participatory Ecological Land Use Management) and its member NGOs. However it is equally apparent that further research is badly needed - many problems still require scientific support, which would ideally go on concurrently with dissemination of findings to date.

3.2 Workshop and field demonstrations of improved IPM approaches

A series of workshops, farmer exchange days and study tours have been carried out. More extension staff/farmer workshops were carried out in March 2001 in order to pilot the pest management handbook (in conjunction with natural enemy project dissemination materials) and to gather further feedback from the farmers about current difficulties and constraints.

On the exchange visits, farmers visited Henderson Research Station to look at the trials in progress. This was judged by the farmers to be a useful exercise in that it gave them confidence that work was in progress on the subjects that they themselves had identified as important. It also helped their general appreciation of the concept of research with some of the differences between treatments being obvious at a glance.

Additional outputs as a result of the one year extension

Extension output 1. Quantification of economic cost of crop protection in the context of other production and marketing costs and constraints

Activities relating to this output were divided into two parts:

- a review of secondary data sources and consultation with key stakeholders (see report by Matsaert and Sithole, 2000);
- a field survey of 4 expanding smallholder vegetable producing areas (see report by Sithole *et al*., 2001).

The review of secondary data revealed the scarcity of existing farm budget information for anywhere outside Mashonaland East, and even this data was not in a standardised format. For example, some data gave revenue per household while others gave gross margins per hectare. Nevertheless, the data examined suggested that crop protection costs were around 10% of total variable costs for smallholder vegetables, but that such investment was nevertheless often accompanied by losses of up to 50% of marketable produce. It also reiterated some of the original justifications for the project i.e. safety hazards for producers, consumers and the environment, build up of resistance, increasing cost of inputs, and destruction of natural enemies.

This initial review indicated that the VPM project farmers did not represent a comprehensive cross-section of the smallholder vegetable farming population – in particular there were imbalances with regard to gender and resource endowment. However, it was recognized that, with the limited resources available to the project, the constituency of farmers had necessarily to be kept small, with inevitable risks of unintentional bias.

At the end of the relatively short four-year initial research period of the project, two major thrusts were planned for a second phase. Firstly to continue to develop improved smallholder pest management methods, and secondly, to expand the influence and dissemination activities of the project into differerent horticulturally important areas.

In order to focus and prioritise the needs for further planned research and dissemination, a month-long field-based socio-economic survey was carried out, covering the two existing project sites, Chinamhora and Mutoko and in addition, two new sites. These were at the Honde Valley (Eastern Highlands) and Esigodini (near Bulawayo). Honde valley was included to try to get a broader picture of constraints for farmers further from large urban centres such as Harare and Bulawayo, and Esigodini was included since it represents a different agro-ecological zone and political/tribal context.

The findings of the survey were as follows:

- Identification of pests and diseases is a major problem – *all* insects were identified as pests.
- There was a lack of knowledge of type of chemicals to use for different pests and diseases. Often, fungicides were applied to control pests.
- Stipulated dilutions were not followed in a number of cases. Generally more chemical than recommended was added per given quantity of water. Sometimes wettable powders were applied as dust.
- There was a lack of knowledge on the significance/meaning of the different triangles on chemical packaging.
- Purple triangle chemicals (very hazardous) were used liberally on leaf vegetables and tomatoes. In most cases these were recommended for use only on cotton and tobacco.
- Minimal use of protective clothing was observed during spraying with pesticides. There was a failure to appreciate dangers associated with contact with pesticides.
- There was poor/careless management of chemicals. In most cases chemicals were:

  a) Not kept under lock and key. In some cases chemicals were kept in the field;
  b) Not kept in their original container. In one case, lime sulphur was being used from a 200 ml diazinon bottle while the large lime sulphur container was kept at home;
  c) Children sometimes as young as 12 were sent to do the spraying.

- Stipulated minimum number of days to wait before harvesting was not being followed particularly when it came to harvesting for the market;

- There is a general belief that recommended chemicals are not as effective as they should be, hence:

    a) use of more concentrated dilutions;
    b) switch to tobacco, cotton and coffee chemicals.

- There was a lack of knowledge of timing of chemical application. Often chemical is applied when disease or pest attack is out of control;
- Some cultural practices employed by farmers to control the disease/pests, actually help keep the problem in the field. These include:

    a) removing diseased leaves and leaving then to rot by the plant;
    b) ploughing in crop residues containing disease/pest;
    c) removing diseased plants, leaving them to rot and returning them later into the field as compost;
    d) removing diseased plants, putting them in the kraal, returning them later into the field with manure.

- Poor quality seed and seedlings of tomato were being sold to farmers by shop outlets;
- There was a lack of knowledge of what comprises a beneficial rotation. Any exchange of crops within a field is termed 'rotation';
- There was generally poor record keeping among smallholder farmers. The utility of such records is generally not appreciated. Where records are kept, they are usually too incomplete to be useful for planning and decision-making;
- Pesticides are generally too expensive for the poorer households, and this combined with the lack of well-developed alternatives resulted in poor households remaining poor since they failed to produce sufficient quantities for marketing;
- Where gardens and/or plots are close together, pest and disease control is negatively affected as the poor, who cannot afford chemicals continue to harbour pests and disease in their plots, which continually re-infest their neighbours;
- With the increase in transportation costs, following increases in prices of fuel, vegetable production is becoming non-viable particularly for areas such as Mtoko where long distances have to be travelled to the market.

And the key research requirements identified were:

- Finding affordable and sustainable crop protection practices within reach of resource-poor farmers;
- Laboratory tests on crops being harvested for marketing by smallholder farmers to ascertain amount of residual chemical available in the light of liberal use of purple triangle chemicals as well as inaccurate dilutions and doses;
- Ascertain whether there is indeed 'resistance' of pests and diseases to certain chemicals;
- Develop and advise on affordable fertilisers within reach of resource-poor farmers;

- Evaluate the potential of botanicals as pest management tools;
- Experiments to determine the effectiveness of different combinations of manure/compost with chemical fertilisers;
- Determine the seed borne pathogen load on retained vegetable seed;
- Determine the time limits for retaining seed before vigour is lost;
- Experiment on appropriate methods of treating retained seed;
- Evaluate the effect of neem products in the control of DBM larvae in brassicas;
- Conduct studies to improve the flow of marketing information to smallholder farmers.

In addition, key extension requirements were identified as:

- Training field staff and vegetable producers on pest and disease identification. This could involve use of colour posters showing the various pests and diseases;
- Running demonstrations on safe use of pesticides. This should include:
    a) type of chemical to use for identified pest or disease;
    b) correct dosages;
    c) timing of pest control measures;
    d) sprayer calibration;
    e) proper dressing and personal protective equipment;

- Training of field staff and vegetable producers on biological control of pests and diseases. This could involve use of colour posters showing natural enemies;
- Training vegetable producers on cultural methods of pest and disease control such as
    a) proper rotation;
    b) disposal of diseased plants or plant parts.

- Training on appropriate crops and cultivars to grow at different times of the year - appropriate for market as well as minimising pests and diseases;
- Providing information to field officers and farmers on a wide range of chemicals to allow for rotation of chemicals;
- Advising input suppliers on the wide range of pesticides available;
- Training and demonstrations on nursery preparation for tomatoes to prevent high losses due to poor germination as well as pest and disease attack;
- Training vegetable producers on the significance of different colour triangles on pesticide containers;
- Providing marketing information i.e. information on prices, alternative marketing outlets etc.

Extension output 2. Further strategies and techniques for sustainable protection of major vegetable crops

Activities under this output included continuation of the RSM control trials in the glasshouse (reported above), development of appropriate calibration guidance and other modules for incorporation into the vegetable pest management handbook.

Extension output 3. Pilot field guidelines for sustainable protection of major vegetable crops produced and disseminated through farmer/extension agent workshops

At the request of the Programme Manager, dissemination workshops were delayed until February/March 2001 so that they could be run jointly with the natural enemy project workshops.

The draft VPM handbook was welcomed by workshop participants, but the formal review process at the first workshop was felt to be asking a little too much of them, despite there being a clear degree of 'teaching by subterfuge' in the process. At the subsequent workshops, only the introduction section was reviewed via group work questions, and the remainder was addressed via interactive group work with the posters.

One poster has been designed as a teaching tool for extension staff to use with farmers in which the elements and technologies of IPM are arranged along a winding road. This winding road metaphor aroused considerable interest and much discussion of the sequencing and content of the side-roads (IPM components) that joined it.

The second poster is intended as a farmer reference (with utility also as a training tool for extension staff) and depicts the major pests and diseases of brassicas and tomato together with the type of pest or disease they are e.g. sucking pest, bacterial disease etc.

Both of these posters are currently in A3 format and the final A1 format will provide four times the poster area to work with. This will allow the IPM poster to incorporate photographs or illustrations to give it greater impact and allow the pest and disease poster to include more detail of identification, damage symptoms and control strategies.

A dissemination add-on has recently been funded by CPP to publish the finalised versions of the VPM handbook (English) and the posters (English, Shona and Ndebele languages) and delivery to Harare is projected to be by September 2001. Feedback is currently awaited from peer review in UK, Kenya and Zimbabwe.

Extension output 4. Skill-sharing to strengthen capabilities of collaborating staff

A study tour was made by two PPRI staff to the cluster of vegetable projects in Kenya being implemented by NRI, CABI Africa Regional Centre and the Kenya Agricultural Research Institute (KARI). This provided useful broadening of experience and skill-sharing with Kenyan colleagues and will improve the quality of inputs to the handbook and subsequent dissemination workshops (see report by Karuma and Mugugu, 2001). This study tour followed study tours to Kenya by 3 other staff members of PPRI (see report by Manyangarirwa, 1999 and Marange and Sithole, 1998)

Extension output 5. Stake-holder's workshop to catalogue all current and planned activities relating to smallholder vegetable production (pre and post harvest) and to identify priorities for research and dissemination

Thirty eight stakeholders from the vegetable sector attended a workshop in Harare on 27 September 2000 to identify constraints to safe and sustainable vegetable production in Zimbabwe. There was broad representation covering small, medium and large-scale enterprises including farmers, government researchers and extension staff, policy makers, NGOs, donors (including a representative from CPP), commercial input suppliers and exporters. The workshop resulted in a series of recommendations on priority areas for research support – see report by Dobson and Cooper, 2000 for full details. The main research areas identified during the workshop are listed below:

- breeding crops for pest and disease resistance, while maintaining palatability to consumers, cosmetic appeal, shelf-life, etc;
- develop improved spray application to achieve efficacy and specificity – collaboration with commercial input suppliers;
- NE studies (identification, conservation, mobility, voracity, impact, production, introductions, conservation, compatibility with IPM systems);
- develop improved *Helicoverpa* control (non chemical and chemical – NPV, Bt [UV protection], pheromones, Mermithid nematodes, *Trichogramma* etc);
- pest/disease forecasting/modelling e.g. 'Blightcast' programme;
- identify bacterial wilt antagonists;
- modelling NE/pest interactions;
- more benign and selective pesticides;
- farmer participatory research methods;
- root knot nematode control (non chemical such as seed-bed solarisation, varietal screening and conservation of NEs);
- mycopesticides and NEs for control of leaf miner, whiteflies (*Bemisia*), thrips;
- reduced dose rates of pesticides and IPM compatible use-patterns;
- resistance monitoring and management;
- validation of biofumigation – details with KARI, Nairobi;
- methods to minimise sprayer operator risk;
- study of the safety and efficacy of botanical mixtures – collaboration with South Africa and CPHP projects;
- systemic activated resistance (SAR) – enhancing plant's own protection;

- efficacy of extracts of *Schwartzia madagescariensis* as a botanical fungicide;
- improved Red Spider Mite control – application, Nes.

Contribution of outputs

Most of the anticipated outputs of the project have been achieved in a timely fashion, although factors such as the departure of two project leaders and the destruction of the Henderson trials by frost and disease in 1999 were setbacks. The slow start to the project and replanting of these trials led to an extra year extension. Further delays were experienced during this additional year due to security restrictions imposed during and after the general elections in July 2000. However, fieldwork continued as soon as possible after this, a large stakeholder workshop was held, and dissemination materials relating to pest management were produced.

The project has contributed to sustainable rural livelihoods in that the outputs will help farmers to produce their vegetable crops (for consumption and sale) in a safer, more effective and economic way. The benefits will include improved nutrition for whole families, reduction of risks from pesticide use and their consumption in the form of residues in produce, better cash returns from higher yields of better quality produce and an empowerment through agricultural knowledge which will help them to make informed choices on other cropping options. Dissemination activities included farmer meetings and exchange days, workshops for extension staff and trainers and study tours for relevant researchers. These have resulted so far in direct benefits to around 80 farmers and 140 extension staff in the form of strengthened skills in pest and disease identification and control. Many hundreds of farmers are expected to benefit indirectly through NGO and extension staff training activities in the coming months and years. Human capital and sustainability of livelihoods has also been enhanced through greater awareness of the health risks associated with pesticides and greater confidence in personal abilities to develop solutions on-farm. It is also likely that multiplication of these benefits will occur as farmers and extension workers advise and influence their colleagues and friends. Feedback from these dissemination activities was used in the refinement of technical material and the means of conveying it, to the extent that the project-trained farmers and extension workers are now in a position to give advice and to make recommendations on a number of important aspects in this large and complex agricultural sub-sector. These messages were disseminated through further workshops in March 2001, involving a larger numbers of farmers and extension staff from a greater diversity of geographical locations and farming systems.

a. What further research is necessary

Improving smallholder vegetable pest management is a complex challenge and there remains much work to be done. The Head and staff of PPRI are strongly in favour of further research work in this area. The stakeholder workshop in October 2000 (see report by Dobson and Cooper, 2000) supported this view and identified a series of remaining problems that need further research support.

This first phase of the project is due to finish at the end of March 2001. A concept note for a second research and dissemination phase has been prepared and submitted to the Crop Protection Programme. This featured a broadened collaboration involving Zimbabwean NGOs, AGRITEX, University of Zimbabwe and Imperial College, UK to produce a strong multi-disciplinary research team, appropriate communication channels and diverse uptake pathways. This concept note was considered to be too research-orientated so a revised version is being prepared with greater emphasis on dissemination, but still retaining some essential core elements of research in order to ensure that subsequent recommendations are fully validated.

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

Smallholder vegetable production provides an important source of employment, income generation and poverty alleviation for many households in rural areas. One of the major constraints in vegetable production systems remains, i.e., loss of crop yield and quality to pests and diseases. Smallholder farmers still rely heavily on the use of pesticides to reduce the damage from pests and diseases. However, excessive and inappropriate use of pesticides can result in residues in produce, induce resistance and be hazardous to human health and the environment, particularly to natural enemies and other beneficial organisms such as pollinators. By developing an integrated pest management strategy for vegetable production which reduces the reliance on pesticides, the volume and quality of vegetable production will be increased in a sustainable way in order to meet the requirements of an expanding urban population. A dependable supply of safe and affordable vegetables is an important requirement for general health, especially low-income households, and fresh vegetables provide vitamins and minerals to supplement the staple cereal diet.

Uptake pathways for the outputs (current and future) of this project and others in Kenya are already in place through the links between PPRI and other parastatal groups, through active collaboration with NGOs including AfFOResT and PELUM, and through more traditional extension services (AGRITEX). These groups and others such as FAO and CABI have expressed interest in the integrated vegetable pest management handbook and posters which are in the final stages of development.

Project reports and publications

Report/publication details	***Electronic file***
CHIIMBA, W. (1999). Report on a visit by Chinamhora VPM farmers to Mutoko VPM farms.	Mutvis2.doc
COX, J. (1998) Report on a Visit to Zimbabwe to assist with the initiation of the pesticide residue analysis component of the RNRRS vegetable pest management project, 21 November - 6 December 1998.	jcrrep2.doc, captemp.doc and coxbtor2.doc
DOBSON, H.M., 1998. To spray or not to spray. Waterlines – International Journal of appropriate technologies for water supply and sanitation. Vol. 17 No. 2.	Waterlin.doc
DOBSON, H.M. *et al*., (1998) Report on Chinhamora and Mutoko Farmers Participatory Meeting Held at Chibanguza Hotel in Murewa on 13 May 1998	fpm_rep2.doc
DOBSON, H.M., and COOPER, J.F. (2000) Report on the Vegetable Pest Management Stakeholder Workshop. 27th September 2000, St Lucia Park Training and Conference Centre, Harare.	final.doc
DOBSON, H.M., MARANGE, T., MANDIVENYI, P., MANYANGARIRWA, W., MUGURI, W., RANGARIRA, R., WESILE, T., and COOPER, J.F. (1997) Report on baseline study of vegetable pests and diseases.	trep97d.pdf
DOBSON, H.M., MANYANGARIRWA, W., CHIIMBA, W., and COOPER, J.F. (2000) Handbook of pest and disease control on tomato and brassica crops in Zimbabwe.	Draft
DOBSON, H.M. and SIBANDA, Z. (1997). Report on site selection survey	siterep.doc
MANYANGARIRWA, W. (1999a) The evaluation of early blight (Alternaria solani) tolerance in different tomato cultivars.	blight3.doc
MANYANGARIRWA, W. (1999b). Report on the study tour of small-scale peri-urban farming households around Nairobi, Kenya (22-31 march, 1999)	karigu2.doc
MANYANGARIRWA, W. (2001). Disease infection levels in tomato seed used by VPM farmers.	Seedsamp.doc
MARANGE, T. and SITHOLE, S.Z. (1998). Report On The Exchange Study Tour Visit To Kenya From 2-11th February 1998	kenyarep.doc
MATTHEWS, G A (1997) Report on a consultancy visit to	zimrep.doc

Zimbabwe 17 - 27th March 1997.	
NZIRAMASANGA, M., (1999) Report on pesticide residue analysis on vegetables.	nozi1.rtf and results2.doc
ODUOR, G.I. and KARANJA, P.K. (1998) Report on the exchange study tour visit to Zimbabwe, 20 – 31 November 1997.	jasrep1.doc
RANGARIRA, R., MANDIVENYI, P., CHARUMBIRA, C., and MUGUGU, W.(1999) Screening of bean and onion types for resistance to root knot nematodes, *Meloidogyne* spp.	vpmrept5.doc
RANGARIRA, R. (1999) Mid-season progress report for nematology, June 1999	midrept.doc
SIBANDA, T. (1999). Back to office Report: XIVth International Plant Protection Congress (IPPC) – Jerusalem, Israel: 25 – 30 July 1999	Btoisr2.doc
SIBANDA, T., DOBSON, H.M., COOPER, J.F., MANYANGARIRWA, W. and CHIIMBA, W. (2000). Pest management challenges for smallholder vegetable farmers in Zimbabwe. Crop Protection 19 (2000) 807-815. (Presented at the XIVth International Plant Protection Congress (IPPC) – Jerusalem, Israel: 25 – 30 July 1999.)	isr16.doc and hard copy
SITHOLE, P. N., SHOKO, T. and MARIGA, K. (2001). Smallholder vegetable production in peri-urban and high potential areas of Zimbabwe: a baseline survey of disease and pest control measures employed	Socencon3.doc
KARUMA J., MUGUGU W. Report on an exchange study tour to Kenya by Staff of the Vegetable Pest Management Project in Zimbabwe 9-15 October 2000.	Studtour2.doc

References

CHIKWENHERE, G. P. and SITHOLE, S. Z., (1993). Integrated Pest Management in Zimbabwe. Proceedings of IPM Working Group IPM Implementation Workshop for East/Central/Southern Africa, Harare, 1993, 83-87.

FAO 1990. Guidelines for personal protection when working with pesticides in tropical climates

GIFAP 1991. Protective clothing for the safe use of pesticides in hot climates

JOWAH, P and MUBVUTA, D. (1993). IPM on cotton in Zimbabwe. Proceedings of IPM Working Group IPM Implementation Workshop for East/Central/Southern Africa, Harare, 1993, 41-52.

KING, W J and DOBSON, H M, 1992. A photographic fluorescent tracer technique for assessing sprayer operator exposure to pesticides. Proceedings of the BCPC Brighton Crop Protection Conference, Pests and Diseases 2, 889-901.

SITHOLE, S. Z. & CHIKWENHERE, G. P., 1995a. The Current Status of IPM in Zimbabwe and Future Direction. FAO/Ministry of Lands, Agriculture and Water Development report prepared under FAO TCP/ZIM/4452 (T), 1995, Section II. 32pp.

SITHOLE, S. Z., and CHIKWENHERE, G. P., 1995b. Report on Pesticide usage by Smallholder farmers. PPRI Internal Report.

VERKERK, R.H.J., D.J. WRIGHT, S.Z. SITHOLE, T. SIBANDA, T. WESILE, G.N. KIBATA, J. ONG'ARO, P. SAMSON, G. ODUOR, P. KARANJA, S. SIMONS, S. MUSIYANDAKA, R. HODZI, F. NYAKANDA, S.L.J. PAGE, A. LITTLE, S. WILLIAMSON & H. DOBSON (1999) Important Natural Enemies of Vegetable Pests in Kenya and Zimbabwe: Recognition and Conservation (Final Draft), Imperial College, London, pp. 49.

VERKERK, R.H.J., 2001. Farmers' Friends: recognition and conservation of natural enemies of vegetable pests in Zimbabwe. Imperial College Press (ISBN …)

WILKINSON, P. (1993). Integrated control of some horticultural pests in Zimbabwe. Proceedings of IPM Working Group IPM Implementation Workshop for East/Central/Southern Africa, Harare, 1993, 31-32.

Appendix 1. Staffing of the VPM project

	1997				1998				1999				2000			
Quarters	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Project Leader	Mr H Dobson															
Project Coordinator	Dr Sithole															
Project Team Leader (in-country)	Mrs Z Sibanda				Mrs T Sibanda					Mr W Manyangarirwa						
Entomologist (Scientist)	Mrs T Sibanda										Joshua Karuma					
Entomologist (Tech. assistant)	Mr T Wesile															
Plant Pathologist (Scientist)	Mrs Mutisi			Mr W Manyangarirwa												
Nematologist (Scientist)	Mrs Z Sibanda							Mr R Rangarira				GAP--------------			Mr T. Ruh	
Nematologist (Technician)	Mr P Mandiveyi													Early retirment		
Nematologist (Technician)	Mrs C Charumbira															
Nematologist (Tech. Assistant)	Mr W Mugugu															
Pesticide Appln. (Scientist)	Mr H Dobson															
Pesticide Appln. (Scientist)	Mr J Cooper															
Research Assistant	Mr W. Munguri				Mr E. Nyamutowa				Mr W. Chiimba							
Residue Chemist	Mrs Nziramasanga															
Res. Chem. Research Officer	Mr Kenneth Chinyama															
Res. Chem. Research Officer	Mr Evans Chavunduka															
Res. Chem. Research Tech.	Christopher Gode															
Res. Chem. Research Tech.	Mrs Eunice Makoni															

Appendix 2. Trials summary for VPM project, Zimbabwe

Title	Crop	Location
Variety trial for disease resistance	Tomato	Chipfupi farm
Early blight tolerance trial	Tomato	Henderson
Test whether diseases are seed-borne	Tomato	Both of above
Aphid threshold trial	Rape	Henderson
Improved application for pest/disease control	Tomato	Henderson
Improved application for pest/disease control	Rape	Henderson
V lance acceptability to farmers	Any	On-farm
Operator contamination trials	Any	On-farm
Varietal tolerance to nematodes	Beans	Henderson
Varietal tolerance to nematodes	Onions	Henderson
Test of residues in produce	Any	On-farm/market
V lance efficacy	tomato	glasshouse
V lance efficacy (2)	tomato	glasshouse