CROP PROTECTION PROGRAMME

Pest management in horticultural crops; integrating sustainable pesticide use into biocontrol-based peri-urban production systems in Kenya.

R6616 (ZA0082/83)

FINAL TECHNICAL REPORT

April 1996 – March 1999

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1. Project summary

TITLE OF PROJECT:	Pest management in horticultural crops; integrating sustainable pesticide use into biocontrol-based peri-urban production systems in Kenya.
R NUMBER:	R6616
PROJECT LEADER:	J Cooper
RNRRS PROGRAMME:	Crop Protection Programme
PROGRAMME MANAGER:	Dr S. Eden Green (NR International)
SUB-CONTRACTOR:	CABI-Africa Regional Centre, KARI, Kenya
CPP PRODUCTION SYSTEM:	Peri-urban
CPP PROGRAMME PURPOSE:	Volume, quality and seasonal availability of food and crop products improved through the reduction of economic and physical losses caused by pests
COMMODITY BASE:	Vegetables
BENEFICIARIES:	Small-holder horticultural farmers around Nairobi
TARGET INSTITUTIONS:	KARI, Kenya
GEOGRAPHIC FOCUS:	Eastern Africa
START DATE:	April 1996
FINISH DATE:	March 1999
TOTAL COST:	£260,213 £116,539 (NRI), £101,504 (CABI-Africa Regional Centre), £42,165 (KARI and MOALDM).

2. Executive summary

Small-holder, peri-urban vegetable farmers in Kenya rely heavily on the use of chemical pesticides to control pests and diseases. This has led to increasing concern about residues in produce, operator exposure, development of resistance and environmental damage, especially to beneficial natural enemies. The cost of pesticides absorbs a significant proportion of farmers' income but currently the farmer is faced with few alternatives. In response to the demand for safer and more judicious use of pesticides through the enhancement of natural control systems, in 1996, CPP commissioned a number of research projects addressing various aspects of research on management of major pests of vegetable crops. The goal of the project reported here was to develop improved methods for insect pest and disease control which integrate the beneficial effects of natural enemies with sustainable pesticide use in small-holder, peri-urban vegetable production systems in Kenya. Research activities were undertaken on-station and on-farm by a collaborative team of entomologists, pathologists and pesticide management specialists from Kenya Agricultural Research Institute (KARI), CABI-Africa Regional Centre (CABI-ARC), Natural Resources Institute (NRI) and the Ministry of Agriculture, Livestock Development and Marketing (MOALDM). Additional inputs were provided by Kenya Institute of Organic Farming (KIOF) and the Global Crop Protection Federation – Safe Use of Pesticides Project.

A Participatory Rural Appraisal (PRA) was undertaken at the start of the project in order to gather information on pest management practices and identify potential farmer collaborators. From the PRA it emerged that four main crops (kale, cabbage, tomato and spinach) accounted for over 95% of peri-urban vegetable production, and these crops became the major focus of subsequent research activities. A series of season-long, on-farm surveys of the four crops grown in contrasting agro-ecological zones and under different management practices i.e. organic and high pesticide use (intensive), led to the prioritisation of the major pest and disease problems and identification of areas of pest management which required improvement.

On brassicas, the most important pests were found to be Diamond Back Moth (DBM), aphids and semi looper while on spinach and tomatoes, leaf miner, aphids, semi looper and thrips were more important. Diseases were not found to be particularly important on brassicas, the most damaging being black rot, ring spot, Downey mildew and virus. In contrast, diseases were found to be extremely damaging on spinach and tomato including early blight, late blight, virus and leaf spot. Clear differences emerged with respect to agro-ecological zone, with the diversity and severity of pests being substantially higher in the lower, warmer locations i.e. Athi River, whereas in higher, cooler locations i.e. Nyathuna, the incidence and severity of diseases was greater. Extensive surveys of natural enemies, particularly of the major brassica pests (DBM and aphids) have revealed a rich diversity of natural enemies, especially on organic farms. Their abundance was also found to be influenced by pesticide regime i.e. natural enemies were more abundant on organic farms, although this could not be correlated with the severity of damage caused by pests and diseases. Pests often caused damage in the presence of natural enemies. A high level of hyperparasitism on parasitoids of aphids was an unexpected finding and further studies are needed to understand these multitrophic interactions in order to quantify the impact of natural enemies on pest management. The potential benefits of using natural enemies in conjunction with more benign pesticides also need to be explored.

Pesticide use was studied, in terms of the choice of active ingredient, quality of application and its effectiveness. Spraying and application methods were found to be imprecise with regard to calibration, distribution, volume applied and safety, which has clear implications for pest management and the environment as a whole. Farmers awareness of the risks associated with using pesticides and the importance of using appropriate methods of application continues to be inadequate among peri-urban vegetable farmers despite the impressive work of the ‘Safe Use of Pesticides’ project. To address some of these problems, a modified spray lance (the V lance) was developed and tested on-station, and was found to deliver a much more even spray distribution on the crop together with a marked improvement in the efficiency of spray application and improved pest control at minimal cost, however, it also had a negative impact on natural enemy populations. Further work is now required to test the lance using more benign or target specific formulations.

The influence of pesticide regime (conventional and non-conventional) on pests, diseases and natural enemies on brassicas and tomatoes was studied in a series of large, multifactorial experiments conducted either on-station or on-farm in contrasting agro-ecological zones over consecutive growing seasons. Non-conventional pesticides included KIOF’s botanical concoction, *Plutella xylostella* Granulosis virus (PxGV), *Bacillus thuringiensis* (Bt) (Kurstaki and Aizawai), neem, Mexican marigold, burnt trash, chillies, hot water and milk. On brassicas, both PxGV and Bt were promising against DBM with only slight or zero impact on natural enemies but none of the non-conventional pesticides were particularly effective against aphids. The standard conventional pesticide, Karate (lambda-cyhalothrin) gave poor control of DBM, which is attributed to insecticide resistance, but good control of aphids. It also had a negative impact on natural enemies. For root knot nematodes on tomato seedlings in the nursery, the treatments appeared to have a limited effect on nematode populations, with only fresh marigold and hot water showing a relatively small reduction in root knot nematode populations. The standard conventional pesticide, Furadan (carbofuran) was found to be ineffective.

Control of tomato blight (early and late), which is the major constraint to tomato production was investigated in a series of experiments on the epidemiology of blight, the extent of tolerance or resistance in different varieties and a comparison of conventional and non-conventional control methods. Late blight was found to be the dominant of the two diseases and frequently masked the symptoms of early blight. None of the tomato varieties currently available in Kenya showed a consistent tolerance or resistance to blight and there was no clear difference between the control treatments although the application of milk did suppress the disease on one of the farms. These experiments need to be repeated before definite conclusions can be drawn.

In addition to the research activities within the main project framework a series of additional complementary 'add on' studies were carried out in collaboration with other researchers through the structure and facilities of the main project. These include: i. A taxonomic revision of the genus, *Orius*, ii. The development and evaluation of a pilot field handbook on natural enemies of vegetable pests, iii. Isolation, identification and application of entomopathogenic nematodes, iv. Isolation and identification of biological control agents of root knot nematode and v. A survey of plant virus diseases affecting peri-urban vegetables. The results of these add-on projects and their potential contribution to the overall goal of the project are discussed in the report.

Active farmer participation has been a key feature of this project from the initial stakeholders meeting through to the PRA and conducting of collaborative on-farm experiments. The farmers and researchers have benefited from regular contact and from a series of participatory meetings and farmer field demonstrations. This enabled farmers' perceptions of the project to be taken into consideration and the farmers themselves have played a significant role in directing the research. In return, farmers' awareness of natural enemies and safe methods of pesticide application has been enhanced through their collaboration in the project. This approach has built up a considerable amount of goodwill between the farmers and researchers and provides an ideal foundation for subsequent phases of the project.

3. Background

The *Purpose* of the Peri-urban Production System is to improve the volume, quality and seasonal availability of food and crop products through the reduction of physical and economic losses caused by pests. The production system is characterised by intensive land use, often high and excessive use of pesticides, and typically produces high value crops such as vegetables. The need to manage pests more effectively through safer and more judicious use of pesticides as well as enhancing natural regulatory systems is inherent in any project implemented to contribute to this purpose. This project was one of a number commissioned by the CPP in 1996 to target output 1 of the Production System.

The majority of smallholder vegetable farmers rely heavily on spraying pesticides to reduce the damage from pests and diseases. These farmers pay little attention to the potential role of natural enemies. The aims of the project were to develop and promote improved methods for the control of pests and diseases affecting the quality and production levels of vegetables in peri-urban areas in Kenya, and specifically to improve pest management methods used by small-holder vegetable growers in the vicinity of Nairobi, who supply the urban population with fresh produce. Major objectives of the project included identification of key vegetable pests and diseases and their potential natural enemies, an assessment of the natural enemies which could be useful in integrated pest management (IPM) systems, studies to determine how pesticide use could be improved, and assessment of alternative pest management strategies.

The project was a collaborative research initiative involving entomologists, pathologists and pesticide application specialists from Kenya Agricultural Research Institute (KARI), CABI-Africa Regional Centre (CABI-ARC), Natural Resources Institute (NRI), and the Ministry of Agriculture, Livestock Development and Marketing (MOLADM). Additional inputs were provided by Kenya Institute of Organic Farming (KIOF) and the Global Crop Protection Federation – Safe Use of Pesticides Project (GCPF – SUP).

4. Project Purpose

Develop improved methods for insect pest and disease control which integrate the beneficial effects of natural enemies with sustainable pesticide use in peri-urban vegetable production systems in Kenya.

Production system Purpose: Improved methods for management of weeds, insect pests, diseases and nematodes in market gardening and horticultural enterprises developed and promoted.

5. Research activities and Outputs

The following 5 activities and outputs are presented in accordance with the original logframe structure in the project memorandum (see Section 7).

Ouputs

1. Improved pesticide application systems which are cheaper and safer for the user in small-scale peri-urban vegetable production
2. An understanding of the effects of pesticides on natural enemy/pest dynamics in

vegetable IPM systems

3. Recommendations on the integration of natural enemies and selective pesticide application for control of key pests in vegetable IPM systems
4. Effective demonstration of low-cost, safe and sustainable IPM methodologies

Output 1: Improved pesticide application systems which are cheaper and safer for the user in small-scale peri-urban vegetable production

Activity 1a: Measurement of spray distribution

Spray distribution from lever operated, knapsack sprayers was measured on the four most important crops on ten farms during 1996 and 1997 cropping seasons. Water sensitive paper targets were used to assess spray distribution on farm crops as the farmers carried out routine pest management operations. Some volume application rates were found to be unexpectedly high (~2,000 l/ha) i.e. >6 times the volume rate required, and 50% of the farmers applied more than 1,000 l/ha. More importantly, it was observed that the majority of dose rates (the amount of active ingredient rather than the volume of spray liquid) differed widely from those recommended i.e. from 6% to 315% of the recommended dose. On most farms, spray distribution was poor (<5% of the lower leaf surface covered), highly variable (from <5% up to 100% leaf surface covered) and gave minimal deposition on the lower surface of the leaves (on average, less than 10% of the surface area covered), where many of the pests and pathogens causing losses are found. Flow rates varied from 2.6 l/min down to 0.8 l/min which is still a relatively high flow rate for a single nozzle used for insecticide application (Cooper *et al*., 1997). ***Completed***

Activity 1b: Development and assessment of modified lance technology

A modified spray lance, which releases spray upwards from within the crop rather than downwards from above, was developed to overcome the problem of uneven spray distribution. Field experiments were established using a randomised block design and repeated over two consecutive cropping seasons to compare the efficiency of spray distribution using the modified lance in comparison with conventional technology. Results showed that a much more even spray distribution could be achieved for minimal expense i.e. the cost of the modified lance (see Fig 1). Using the conventional lance, there was <50% reduction in pests and natural enemies whereas with the modified lance there was almost complete control of pests and natural enemies compared with the unsprayed control (see Fig. 2). ***Completed***

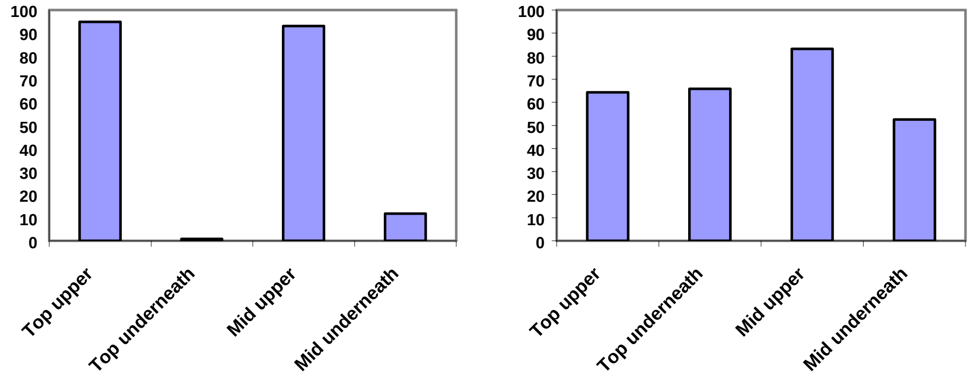


Fig 1: Comparison of spray distribution on kale (percentage area cover) using a conventional lance (left) and a modified lance (right)

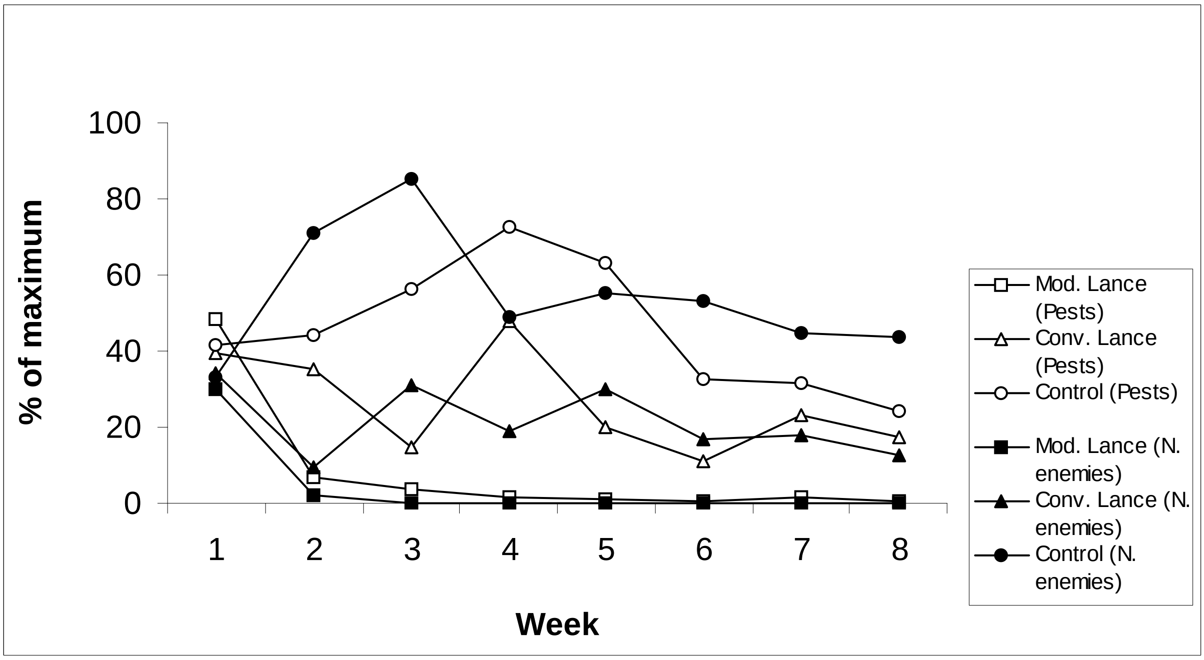


Fig 2: Effect of pesticide applications on pest and natural enemy populations, with a conventional lance (ν), a modified lance (σ) and a control (λ)

Activity 1c: Assessment of operator exposure when applying pesticides

Operator exposure was assessed qualitatively using a fluorescent tracer technique. Five farmers were provided with ‘oversuits’ to wear whilst carrying out a spraying operation. An invisible fluorescent dye was added to the spray mixture in the tank prior to spraying and the suits were subsequently assessed photographically in the UK using ultraviolet light to identify the area of the body contaminated by spray. Considerable deposits were visible on the legs and lower body, indicating contamination by pesticide. ***Completed***

Conclusions

Using existing application technology, spray distribution on the crops was uneven, particularly on the undersurface of leaves, and ground deposits were often high, indicating that a considerable amount of pesticide is being wasted. This has clear implications for pest management and the environment as a whole. Efficiency of spray application was markedly improved using the modified lance at minimal cost, however, it also had a negative impact on the natural enemy populations. Further work is now required to test the lance on more benign or target specific formulations such as *Plutella xylostella* Granulosis Virus (PxGV) and to determine whether with improved application efficiency, such as that achieved using the modified lance, it would be possible to reduce dose rates. Poor nozzles are undoubtedly affecting the volume application rate and the spray distribution but it was disappointing to note that in Nairobi, replacement spray nozzles were not available for sale in the three major horticultural supply distributors. Farmers' awareness of the risks associated with using pesticides and the importance of using appropriate methods of application continues to be inadequate among peri-urban vegetable farmers, despite the impressive work of the 'Safe Use of Pesticides' Project in Kenya. A significant quantity of pesticide was found on the protective suits used in the trials, which indicates that farmers - who often wear little or no protective clothing - are being heavily exposed to the pesticides they are using.

Output 2: A ranked list of potentially useful natural enemies and an evaluation of their effectiveness in natural suppression of important pests

Activity 2a: Participatory Rural Appraisal (PRA)

Prior to the commencement of this project, a stakeholders meeting, with participants from MOALDM, KARI, CABI, NRI, GTZ, ICIPE plus NGOs, was held at KARI (September 1995) to discuss IPM research issues and in particular, how new RNRRS research proposals would complement existing programmes in Kenya. The stakeholders meeting was followed by a socio-economic evaluation which was undertaken to identify the main constraints to small-holder vegetable production in Kenya and to recommend suitable locations for the proposed research project (BTOR VS3177 & FILE NOTE VS3177; November 1995). As part of the evaluation, two locations, Ngong and Loitokitok were visited and recommended, however, both locations were subsequently ruled out on the basis of logistical considerations. Thus, at the beginning of the peri-urban vegetable project (R6616), it was necessary to undertake a participatory rural appraisal in order to gather information on pest management practices in vegetable production systems in and around Nairobi and to identify potential farmer collaborators. A questionnaire was developed as a guide to standardise the information collected and farmer interviews were conducted by KARI and CABI in collaboration with MOALDM Extension Officers (Nyambo *et al*., 1996). ***Completed***

Activity 2b: A baseline survey of pests, natural enemies and pesticide regimes in contrasting agro-ecological zones

On the basis of the PRA, 12 farmers - 6 in each of two contrasting agro-ecological zones (Nyathuna and Athi River), were selected and a baseline, on-farm survey was carried out. Data on the incidence and severity of pests, diseases and natural enemies, as well as pesticide use (type and frequency), were collected from each farm on a weekly basis throughout an entire cropping season. In order to catalogue the natural enemy populations, specimens (>50) were sent to CABI-Bioscience (formerly CABI's International Institute of Entomology) for taxonomic identification (Maxen, 1997) whilst pests and diseases were identified at KARI's Plant Disease Clinic. At the end of the growing season, harvested crops were analysed for pesticide residues at KARI's Analytical Laboratory. Details of the baseline survey are described in the 1996/7 Annual Technical Report (Cooper *et al*., 1997). Table 1 contains the pest and natural enemy specimens collected and identified. ***Completed***

Conclusions

On-farm assessments of 10 different crop species (72 crops in total) revealed that kale, cabbage, tomato and spinach were the most commonly grown vegetables. A wide range of pests and diseases were recorded and clear differences emerged due to the effect of agro-ecological zone. The diversity and severity of pests was substantially higher in Athi River, which is lower and warmer, while the incidence and severity of diseases was higher in Nyathuna. At both locations, populations of natural enemies were far lower than expected and did not appear to be influenced by agro-ecological factors. The paucity of natural enemies was primarily attributed to the long history of pesticide use in both locations. However, from the taxonomic identifications, it emerged that a number of natural enemies were, in fact, hyper-parasitoids e.g. 20% of 'parastoids' sent for identification from the baseline survey were actually found to be hyper-parasitoids. Clearly the role of hyper-parasitoids in the production of peri-urban vegetables warrants further investigation.

It is clear that the majority of vegetable crops are receiving an incorrect pesticide dose. Only 22% of the applications observed (several products were applied simultaneously) were within 25% of the recommended dose rate (Cooper *et al*., 1997). Although manufacturers indicate how much spray should be applied to crops on the pesticide label, the way the information is expressed varies from product to product, so it is easy for farmers to be confused about how much to use, even when they measure both the quantity of concentrated pesticide added to the tank and the volume of spray mixture sprayed onto the crop. Sometimes label instructions give a tank dilution (e.g. add 30ml to a 20 litre sprayer), assuming an unstated volume application rate (l/ha), while others give the quantity needed per hectare, leaving the farmer to work out how much to add to each spray tank. And in most cases, this ambiguous or incomplete label information resulted in under-dosing or over-dosing. Both are undesirable - the former risks failure, and leaves surviving pests to breed, which encourages development of resistance to the pesticide, whereas too much pesticide is uneconomic and leads to excessive residues on harvested crops.

Spray residues on harvested crops are an important issue in Kenya. Not only do they indicate possible excessive dose rates, but also non-observance of the pre-harvest interval (the safe time limit between spraying and harvesting crops). Eight harvested crops were sampled from six farms, and analysed for presence of the commonly used pesticides (Cooper *et al*., 1997). According to KARI Analytical Laboratories, only mancozeb on tomatoes showed significant residue levels (0.32mgCS/Kg), but the validity of the analyses is questionable. Standard reference materials (pesticides) used in the analyses were past their expiry date and had been subjected to wide temperature fluctuations because of problems with the electricity supply to the freezers. This might explain the unexpectedly low residues, even on produce harvested from crops sprayed immediately prior to harvesting.

Table 1: Specimens collected and identified during the project

ORDER	FAMILY	SPECIES	PEST/N.ENEMY	REGION COLLECTED
SPECIMENS IDENTIFIED IN AUGUST 1997				
ARACHNIDA	**Lycosidae**	*Pardosa* sp.	Predatory Spider	N
COLEOPTERA	**Anthicidae**	*Anthicus biplagiatus* Laferte-Senectere	Predatory Ant	N
		Formicomus rubricollis Laferte-Senectere	Predatory Ant	N
	Curculionidae	*Systates pollinosus* Gerstaecker	Pest on many crops	N
	Staphilinidae	*Oxytelus planus* Fauvel	Predator	N
	Tenebrionidae	*Gonocephalum simplex* (Fabricius)	Detritus feeder	N
		Phrynocolus sp.	?	N
		Zophosis congesta Gerstaecker	?	N
DIPTERA	**Anthomyiidae**	*Delia* sp.	Pest	N
	Asilidae	*Machimus* nr *juxta* Oldroyd	?	N
	Tachinidae	*Gonia bimaculata* Wiedemann	Parasitoid of *Agrotis*	N
		Nemoraea rubellana Villeneuve	Parasitoid of *Agrotis*	N
		Palexorista sp. nr *zonata*	Parasitoid of *Agrotis*	N
		Periscepia carbonaria Panzer	Parasitoid of *Agrotis*	N
HEMIPTERA	**Lygaeidae**	*Geocoris* sp.	Predator	N
	Pentatomidae	*Bagrada hilaris* Bermeister	Pest	N
HYMENOPTERA	**Braconidae**	*Meteorus* sp.	Parasitoid of e.g. *Agrotis*	N
		Diaretiella rapae (M'Intosh)	Parasitoid of aphids	N
		Cotesia (Apanteles) ruficrus (Haliday)	Parasitoid of Lepidoptera larvae	N
	Figitidae	Cynipoidea *Alloxysta* sp.	Hyperparasitoid of aphid Braconid parasitoid	N
	Encyrtidae	*Syrphophagus africanus* (Gahan)	Predator of aphids	N
	Eulophidae	*Diglyphus* sp.	Parasitoids of Dipteran Leaf miners	A
		Oomyzus sokolowski (Kurdjumov)	Parasitoid of DBM and its Brac. Parasitoids	A
	Ichneumonid	*Diadegma* sp.	Parasitoid of DBM	N
	Megaspilidae	*Dendrocerus* sp.	Hypers of Braconid and Chalcid parasitoids	N
	Pteromalidae	*Asaphes* sp.	Hypers of aphid Braconid parasitoids	N
		Pachyneuron sp.	Hypers of Syrphids, paras of aphids, coccids	N
	Scelionidae	*Telenomus* sp.	Parasitoids of Lepidoptera eggs	N
ORTHOPTERA	**Acrididae**	*Chrotogonus hemipterus* Schaum	Pest	N
	Oedipodinae	*Trilaphidia contortata* Walker	Pest	N
SPECIMENS IDENTIFIED IN JANUARY 1998				
DIPTERA	**Agromyzidae**	*Liriomyza huidobrensis* (Blanchard)	Polyphagous pest	N
	Tachinidae	*Palexorista laxa* Curran	Parasitoid of Lepidoptera larvae	N
HEMIPTERA	**Aphididae**	*Aphis fabae* complex	Polyphagous pest	N
		Macrosiphum euphorbiae (Thomas)	"	N
HYMENOPTERA	**Braconidae**	*Glyptapanteles maculitarsis* (Cameron)	Parasitoid of DBM	N
		Microchelonus curvimaculatus Cameron	Parasitoid of DBM	N
		Aphidius colemani Viereck	Parasitoid of aphids	N
		Aphidius sp. nov.	"	N
	Chalcididae	*Brachymeria* sp.	Parasitoids of pupae of DBM, etc	N
	Eulophidae	*Diglyphus isaea* (Walker)	Ectoparasitoid of leaf miners	N
		Meruana liriomyzae Boucek	Parasitoid of leaf miners	N
		Neochrysocharis sp.	Egg parasitoids of leaf miners, Leps. Etc	N
	Ichneumonidae	*Charops* sp.	Parasitoid of Lepidoptera	N
		Mesochorus sp.	Hyperparasitoids	N
THYSANOPTER	**Thripidae**	*Ceratothripoides* sp.	Pests	N

Note that N and A denote the regions of Nyathuna and Athi River respectively

Output 3: An understanding of the effects of pesticides on natural enemy/pest

dynamics in vegetable IPM systems

Activity 3a: Measurement of the impact and persistence of pesticides on natural enemies and pests in treated crops.

Following the results from the baseline survey, where unexpectedly low numbers of natural enemies were observed, a more detailed comparison was undertaken in which the effect of conventional pesticide regimes were studied and compared with a control (organic) in the same agro-ecological zone (Nyathuna) for their effect on natural enemy abundance. Farmers who grew their vegetables organically had all undergone training with the NGO, Kenya Institute of Organic Farming (KIOF) and were selected in collaboration with KIOF. On the basis of the baseline survey, the four most commonly grown crops were selected and monitored for pest, disease and natural enemy populations on twenty farms (10 high pesticide and 10 organic) just prior to harvesting (spatial experiment), and on three farms (high pesticide, intermediate pesticide and organic) at weekly intervals throughout an entire cropping season (temporal experiment). Table 2 provides a summary of the three most important pests, diseases and natural enemies in each crop, and Fig 3 shows the effect of pesticide regime on natural enemies. The experiments were conducted on-farm and were non-interventional, so spray regimes often involved more than one pesticide. It was, therefore, not possible to rank the effects of different pesticide products. Specimens of all natural enemies, together with unusual pests and diseases which required further examination were sent to CABI-Bioscience UK for taxonomic identification while identifications and residue analyses were again carried out by KARI. ***Completed***

Activity 3b: A taxonomic revision of the genus, *Orius*, pirate bugs in East Africa (ZA0083)

An add-on project was undertaken in order to provide a taxonomic revision of the genus, *Orius,* in East Africa. Several species of pirate bug within the genus *Orius* are important predators of eggs and larval stages of pests of vegetable crops, and a comprehensive list of useful natural enemies at the species level was required. A review of the economically important species of the genus *Orius* (Heteroptera: Anthcoridae) in East Africa by Hernandez, L. and Stonedahl, G. (1999) has been published. ***Completed***

Activity 3c: Development and evaluation of a pilot field handbook on natural enemies of vegetable pests in Kenya (ZA0083) and Zimbabwe (ZA0054)

This 6 month short project (R7266, NRIL code ZA0250) was undertaken as an add-on to ZA0082/83 and ZA0054 (1 October 1998 – 31 March 1999) to build on improvements in understanding of the current and potential role of natural enemies in vegetable production systems, and to strengthen the capacity for dissemination of this knowledge to farmers. The latter objective was met primarily by the production of a pilot field guide for use by extension workers/trainers, a poster and a natural enemy pocket guide for farmers. ***Completed***

Conclusions

Pesticide regime had a highly significant effect on the abundance of pests (with the exception of DBM), diseases and natural enemies. The apparent lack of effect on the numbers of DBM in the spatial experiment i.e. 1.4 under high pesticide application compared with 0.6 DBM per plant when grown organically is probably indicative of DBM resistance to the most commonly used insecticide, lambda-cyhalothrin (Karate). It is interesting to note that in general, the ranking, in terms of importance, does not vary with pesticide regime but the actual numbers of pests and natural enemies do. Data for the severity of damage caused by pests and diseases were analysed and correlated with the abundance of natural enemies in order to quantify their effect in controlling pests. In addition to the insects listed in Table 2, other natural enemies were collected including the predatory bug, *Orius* and the fungal entomopathogen, *Zoophthora radicans* which attack DBM. Taxonomic identifications revealed a considerable number of hyper-parasitoids but their impact on natural enemy populations remains to be quantified. Natural enemies were relatively more abundant on organic farms whereas intermediate and high pesticide regimes resulted in a significant (and similar) reduction in natural enemy populations. The benefits of natural enemies should now be explored in conjunction with the possibility of using relatively selective yet effective pesticides which are compatible with natural enemies.

Table 2: Summary of importance of pests, natural enemies and diseases

Factor	Cabbage	Kale	Spinach	Tomato
Most abundant pests	DBM Aphids Trichoplusia	DBM Aphids Whitefly	Aphids Trichoplusia Leaf Miner	Leaf Miner Thrips Aphids
Most damaging pests	DBM Aphids Trichoplusia	DBM Aphids Trichoplusia	Trichoplusia Leaf miner Aphids	Bollworm Leaf miner Thrips
Most abundant natural enemies	Syrphids Spiders Ants	Syrphids Spiders Ants	Spiders Ants Coccinellids	Ants Spiders Coccinellids
Most damaging diseases	Black Rot Ring spot Downy mildew	Black Rot Downy mildew Virus	Cercospora Virus	Early blight Late blight Virus

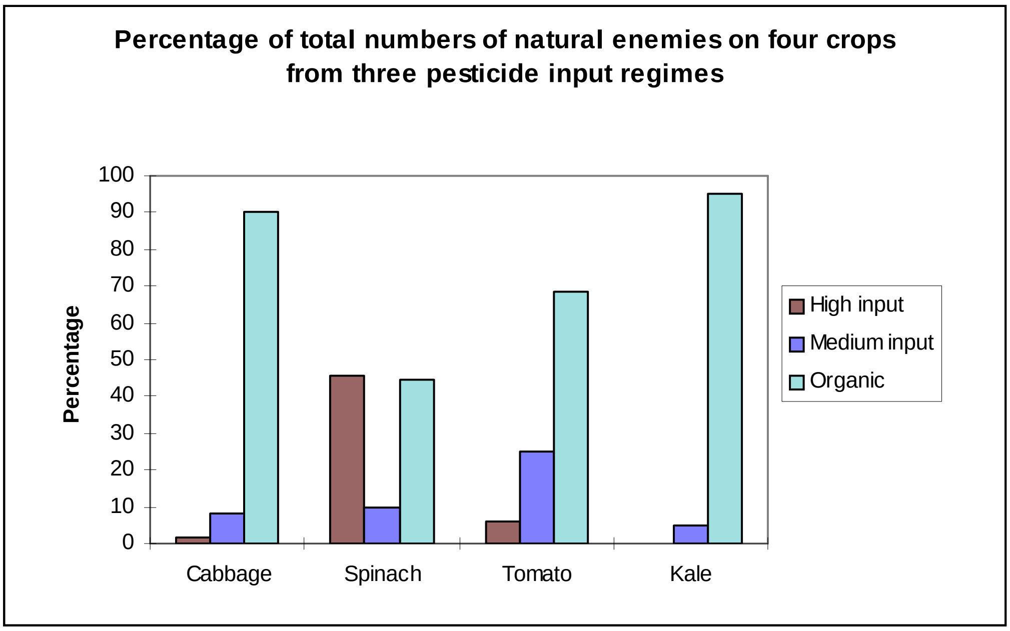
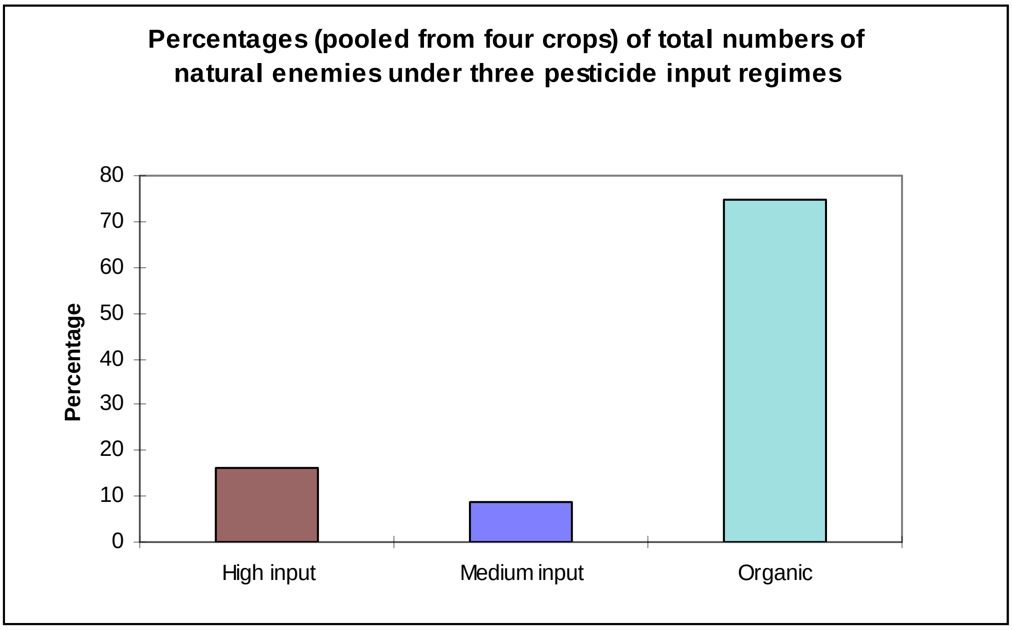


Fig. 3: Percentage of total number of natural enemies on four crops (top) and pooled (next page) under three pesticide input regimes



Output 4: Recommendations on the integration of natural enemies and selective pesticide application for control of key pests in vegetable IPM systems

Activity 4a: Comparison of non-conventional pest management strategies to control pests, particularly DBM and aphids on Kale

A multifactorial field experiment was carried out to compare the effects of five non-conventional pest management strategies i.e. neem, PxGV (in collaboration with the 'biorationals' project), two different strains of *Bacillus thuringiensis* (Bt) i.e. Kurstaki and Aizawai, and KIOF's botanical concoction (in collaboration with KIOF), plus a conventional pesticide (lambda cyhalothrin) and an untreated control, in a randomised block design. Pest and natural enemy populations were assessed each week throughout two consecutive growing seasons. Results are summarised in Fig. 4. ***Completed***

Activity 4b: Comparison of non-conventional pest management strategies to control root knot nematode (RKN) on tomatoes

A multifactorial experiment was established at farms in two contrasting agro-ecological zones to compare the effect of four non-conventional pesticides i.e. fresh marigold, dry marigold, hot water and burnt trash, plus one conventional pesticide, carbofuran (Furadan) and a control treatment on the incidence of RKN in tomato seedlings in the nursery. The two field sites were at Githunguri and Karigu-ini and data were collected 2, 3 and 4 weeks after planting. The effect of the treatments on the germination of tomato seeds was not significant at Githunguri but significant ($p=0.21$) at Karigu-ini. Burning trash on the nursery before planting led to superior germination at the latter site. There was a significant effect ($p<0.05$) of the treatments on the average shoot and root lengths of the tomato plants throughout the sampling period. High initial temperatures in the nursery soils (trash burning and hot water) led to longer shoots. The different treatments affected the nematode population only in the second week ($p=0.04$), with fresh marigold and hot water leading to the lowest nematode population (1.6, on a scale of 0 to 10) (Fig 5). ***Completed***

Activity 4c: Comparison of 4 different tomatoes varieties on the epidemiology and control of blight (early and late)

Multifactorial experiments were established at farms in two contrasting agro-ecological zones to compare the effect of variety on the incidence and severity of blight (early and late) on tomatoes, and to compare the efficacy of two conventional pesticides (Ridomil and Dithane) with two non-conventional pesticides (milk powder and chillies), plus a control treatment. Late blight was the dominant of the 2 blight diseases and frequently masked symptoms of early blight. Due to 'unfavourable' climatic conditions the disease did not set in until 3 months after the seeds were planted. The variety, Moneymaker showed high susceptibility to late blight at both sites, relative to other varieties tested i.e. Cal-J, Roma and Arletta. No variety showed a consistent lower susceptibility to the disease. However, the variety, Arletta suffered a lower disease severity than did Moneymaker and Roma in the last 3 weeks at Karigu-ini. Due to its high susceptibility to blight, Moneymaker was used in a trial comparing the different control strategies against this disease. As in the varietal experiment, late blight set in late and increased in severity as the season progressed. The untreated control suffered the highest diseases severity at both sites. There was no clear difference between the other treatments, although milk appeared to suppress the disease better (Fig. 6). These experiments need to be repeated before definite conclusions can be drawn. ***Completed***

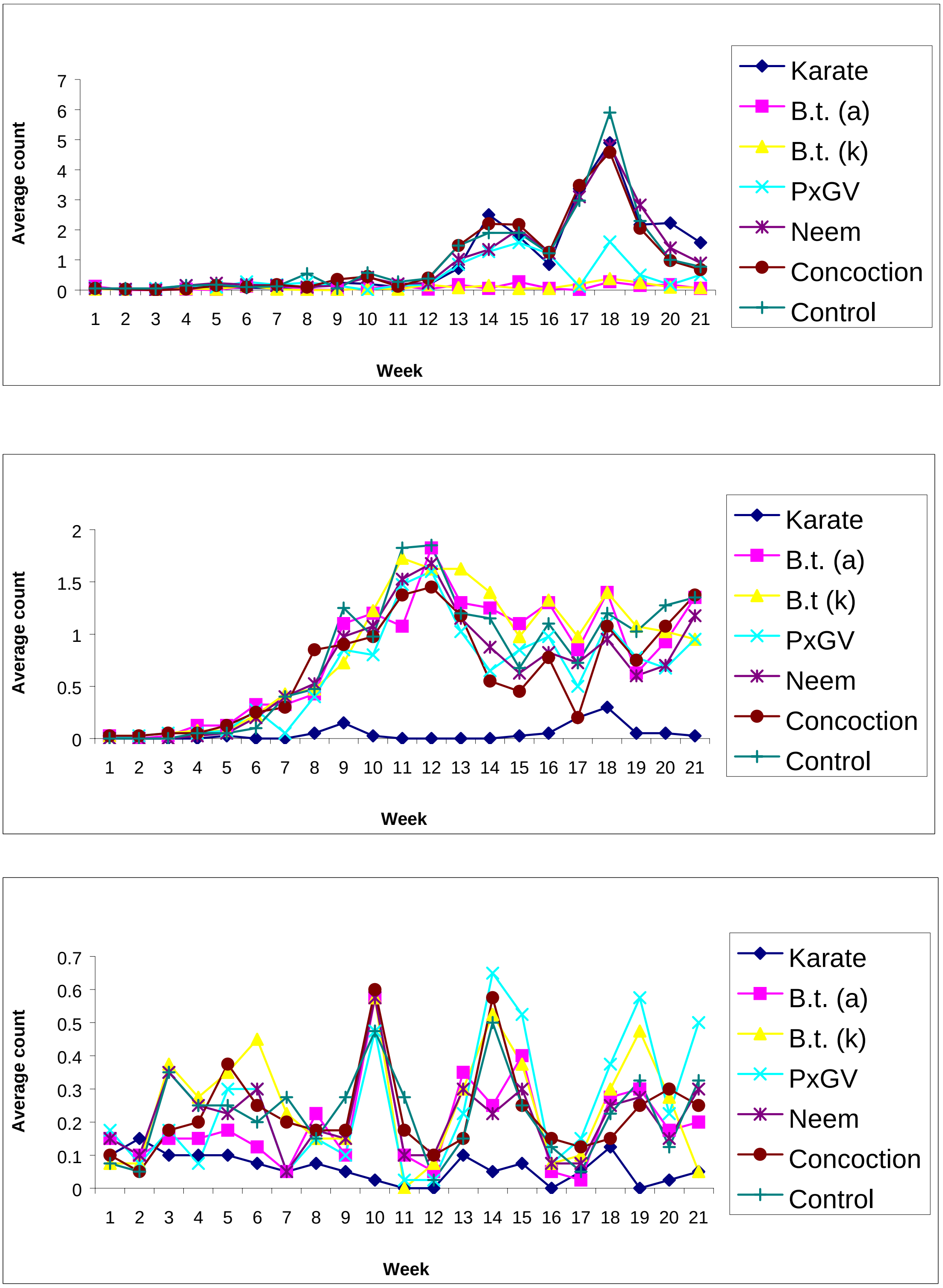


Fig. 4: Effect of non-conventional pest management strategies on the temporal progress of Diamond Back Moth (top), Aphids (*Brevicoryne* sp.) (middle) and natural enemies (lower). Bt (a) and (b) are *Bacillus thuringiensis* Aizawai (a) and Kurstaki (b).

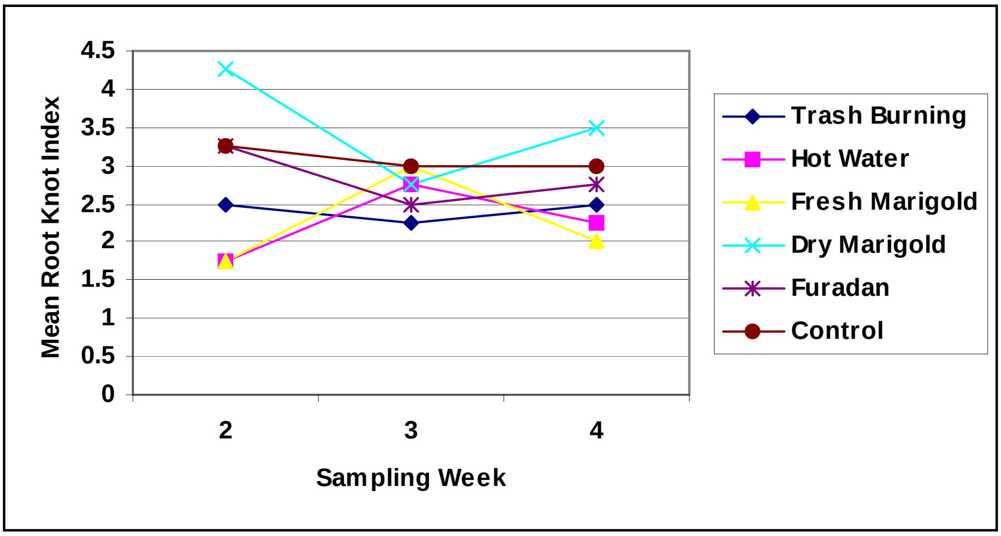


Fig 5: Showing the effect of different treatments on root knot nematodes

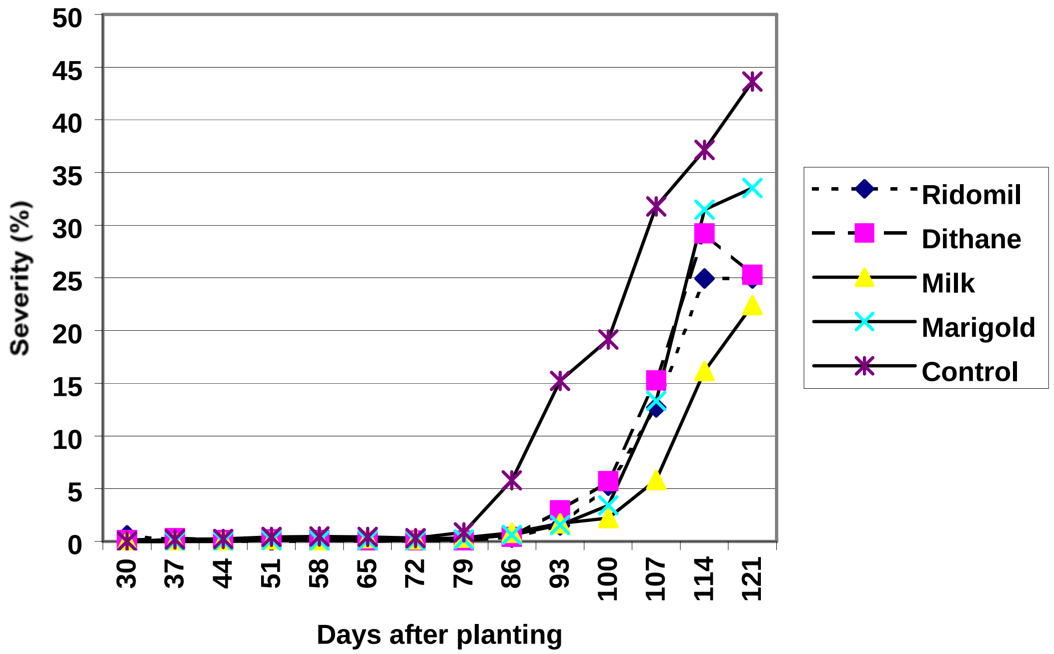


Fig. 6: The severity of late blight on different cultivars of tomato (top) and on tomato treated with different fungicides.

Activity 4d: Isolation, identification and culture of indigenous entomopathogenic nematodes and preliminary investigations into their use for control of insect pests of peri-urban agriculture (ZA0196)

An 'add-on' project was undertaken between 1st February – 31st March 1997 to isolate, identify and culture entomopathogenic nematodes from soils at the farms collaborating in the peri-urban vegetable project. Existing and newly isolated nematodes were screened for effectiveness against cutworms in laboratory assays. KARI staff were also trained in the techniques required. ***Completed***

Activity 4e: The application of entomopathogenic nematodes from the laboratory to the field and the identification of new isolates of entomopathogenic nematodes (ZA0083)

Following on from the successes of the above add-on (ZA0196), a second add-on project was undertaken between 10th October 1997 – 31 March 1998 to take the application of nematodes from the laboratory to the field, identify new isolates of potential entomopathogenic nematodes and conduct preliminary assays in the field. Infection of cutworms (*Agrotis* sp.) by two entomopathogenic nematodes (*Heterorhabditis bacteriophora* and *Steinernema karii*) was confirmed in the laboratory and subsequently in the field. ***Completed***

Activity 4f: A survey of plant virus diseases affecting peri urban vegetables

In February 1999 a survey of virus diseases in vegetable production on farms around Nyathuna was carried out (ZA0272, a NRIL Programme Development project). Seventy-seven samples were collected from 18 different vegetable crops from 14 different farms. Possible virus symptoms of each sample were recorded in Kenya, and on return to the UK each sample was inoculated to a range of host indicator plants of different species and also tested for several known viruses using ELISA. Samples of each crop were also examined using an electron microscope (EM). After 7-10 days symptoms had developed in many of the indicator species. Cabbage, cauliflower and kale crops were found to be almost 100% infected with combinations of turnip mosaic virus, cauliflower mosaic virus and beet western yellows virus. Pepper crops were 100% infected with combinations of pepper mild mottle virus and potyvirus. Cucumber and spinach crops were also severely affected by potyviruses, and other crops which were virus-infected included celery, pumpkin and lettuce. ***Completed***

Activity 4g: Isolation and identification of biological control agents of Root Knot Nematode (R6611, NRIL code ZA0078)

Following reports of serious nematode infestations on a number of peri-urban vegetable farms, an add-on project was undertaken in collaboration with A0671/A0518 to quantify the incidence and severity of root-knot infestations, identify isolates of the potential biological control agents, *Verticillium chlamydosporium* and *Pasteuria penetrans* and screen for their potential in the management of root-knot nematode populations. No significant RKN infestation was recorded from farms in Nyathuna (Kiambu) or Athi River and Mua (Machakos). However, extensive RKN damage to tomato was observed in Mwea, Ndia and Kibirigwi (Kirinyaga), Karigu-ini (Maragua), Kenya Seed Company (Thika) and Kaluluini (Machakos). Lower incidence of this nematode was recorded in Rongai and Subukia (Nakuru), Mathira and Kieni (Nyeri) and Gachoka (Embu). All tomato varieties sampled (Cal-J, Moneymaker, Kentom and M82) were found to be susceptible. Taxonomic identification of the RKN is still to be done. Yield losses due to RKN were estimated to be between 50 and 60% and less than 50% of the farmers attempted to control this pest, mainly due to lack of funds, but also due to toxicity and ineffectiveness of the nematicide (especially Furadan). Although 72% of the farmers were aware that the galls on the roots of the plants were associated with yield losses, only 24% knew that the galls were caused by RKN. All farmers interviewed had interests in farmer field schools. The entomophagous fungus, *Verticillium chlamydosporium* was isolated from 78% of the soil samples collected. The biological control potential of this fungus against RKN was also tested in the laboratory. Although *V. chlamydosporium* colonised the rhizosphere and produced chlamydospores on a sand:milled barley medium, the parasitism of eggs of the RKN, *Meloidogyne incognita* was low, ranging from 3 to 42%. The nematicidal effect of the KIOF concoction on the viability of eggs and survival of second stage juveniles of *M. incognita* was also tested in the laboratory. Whereas a 75% solution (i.e. 3 parts concoction and 1 part water) led to a 99% reduction in egg viability after 24 hours, a 5% solution of the same caused a 61% reduction in egg viability after 120 hours. Juveniles of *M. incognita* were more sensitive to the concoction than were eggs, showing a 100% mortality after 24 hours even when a 5% solution was used. Training was also provided for KARI and CABI staff in methodologies associated with the use of these biological control agents and in general nematology. ***Completed***

Conclusions

In agreement with observations made during the spatial experiment described in 3a, the widely used pesticide, lambda-cyhalothrin (Karate) gave poor control of DBM i.e., not significantly different from the control treatment. The same product gave good control of aphids (*Brevicoryne* sp.) but had a negative impact on natural enemies (see Fig. 4). Both strains of Bt (Kurstaki and Aizawai) and, to a lesser extent, PxGV were promising against DBM with only a slight (or nil) negative impact on natural enemies. In the case of Bt, however, because of control problems at one of the experimental sites, further investigations into resistance management are required before it can be incorporated into an integrated strategy. As would be expected, PxGV had no effect on anything but DBM. It was particularly disappointing to observe the poor performance of the KIOF ‘concoction’, a botanical formulation which is widely used by organic, peri-urban vegetable farmers, although it would be useful to compare the farmer-prepared KIOF mixture used in these experiments with others - the recipe promoted by KIOF does not specify the quantities of the individual ingredients. None of the non-conventional pesticides was particularly effective against *Brevicoryne* which is the second most important pest of brassicas.

Root knot nematode studies indicated that they are a very serious problem on tomatoes in some areas. The commonly used pesticide was less effective than some of the unconventional treatments such as soil heating by burning trash or using hot water. Marigold soil treatment also gave some control, but clearly a more effective and reliable methods are required. Biological control using Kenyan isolates of the two agents, *Verticillium* or *Pasturea* may be the answer. Having been proven in the laboratory the organisms now need to be assessed on-farm. All locally available tomato varieties were found to be seriously affected by late blight disease. Some control was achieved experimentally using sprays of fresh milk, and it will be interesting to determine whether the lower rates recommended by KIOF give significant benefits. However a major requirement is for resistant planting material and this is one of the planned activities in the proposed phase II.

Plant virus diseases were found in samples taken from almost all brassicas and peppers collected from farms. It is likely that yields are being significantly reduced. The extent of this viral infection and the source of the infection (whether largely seed-borne or spread by invertebrate vectors) remains to be determined.

Output 5: Effective demonstration of low-cost, safe and sustainable IPM methodologies

Activity 5a: Peri-Urban Vegetable Farmers Participatory Meeting

A one-day Peri-Urban Vegetable Farmers Participatory Meeting was held at the National Agricultural Research Laboratories of KARI on 4th February 1998. 45 farmers (25 male and 20 female) participated in the meeting which was jointly hosted by NRI, CABI, KARI and MOALDM. The purpose of the meeting was to bring together all of the collaborators currently involved in the peri-urban vegetable project, to provide an opportunity for discussion and exchange of ideas between scientists and farmers. The meeting started with a lively introduction by an IPM facilitator, Mr Martin Kimani (CABI-ARC), which was followed by a brief overview of achievements to date (Dr George Oduor, CABI-ARC). Two of the farmers (one an organic farmer and the other, a pesticide user) then led a stimulating discussion on farmers' perspectives of the project, and in particular, on natural enemies, which many of the farmers were unaware of prior to their involvement in the peri-urban project. The final session was a discussion on the activities planned the next phase i.e. the third year on the project and a re-assessment of farmers needs following the first two years of the project (Mr Peter Karanja, CABI-ARC). ***Completed***

Activity 5b: Farmer field demonstrations in two horticultural crops in each of two peri-urban locations

i. Farmers field demonstrations held on-farm at Nyathuna (February 1999) - twenty of the farmers who participate in the project attended the demonstration.
ii. A farmer participatory workshop, involving twenty farmers from five different districts of Kenya, on the importance of natural enemies of vegetable pests was held at Nakuru (March 1999).

6. Dissemination

6a. Publications:

Mwaniki, S., Kibata, G., Pete, S., Kamau, J., Dobson, H. & Cooper, J. (1998) Pest management in peri-urban vegetable systems in Kenya: Spray application rates and distribution in the crop. In *Proceedings of the Second Biennial Conference on KARI/DFID NARP II Crop Protection Programme, 16-17 September 1998. pp 1-11.*

Oduor, G., Ongaro, J., Pete, S., Karanja, P., Cooper, J., Mwaniki, S., Kibata, G. & Simons, S. (1998) Pests of horticultural crops on small-scale peri-urban farms in Nyathuna, Kiambu: Influence of pesticide regimes on pests and natural enemies. In *Proceedings of the Second Biennial Conference on KARI/DFID NARP II Crop Protection Programme, 16-17 September 1998. pp18-29.*

6b. Internal Reports:

BTORs, Quarterly reports and Annual reports

Project Reports (in chronological order):

1996

Nyambo, B.T., Kibata, G., Ongaro, J., Mwangi, T., Karanja, P., Ngo'obe, A. & Onyango, R. (1996) Selection of potential farmers for project collaboration: Summary of the first questionnaire results (31 July – 15 August 1996).

1997

Briscoe, B.R. (1997) Report on the isolation, identification and culture of indigenous entomopathogenic nematodes, and preliminary investigations into the use of indigenous entomopathogenic nematodes for the control of insect pests of peri-urban agriculture in Kenya.

Cooper, J., Dobson, H., Kamuyu, L., Karanja, P., Kibata, G., Mwaniki, S., Namu, L., Ngatia, J., Nyambo, B., Odhiambo, B., Ongaro, J. & Simons, S. (1997) Technical Report on pests, natural enemies and pesticide use on vegetable farms around Nairobi (1 April 1996 - 31 March 1997).

Kibata, G.N. & Ongaro, J.M. (1997) Report on an exchange study tour visit to Zimbabwe (20 – 31 October 1997).

Mwaniki, S., Pete, S., Kamau, J., Dobson, H., and Cooper, J. (1997) Spray application report.

Oduor, G., Pete, S., Simons, S., Mwaniki, S., Cooper, J. & Dobson, H. (1997) Effect of using a modified spray lance on populations of pests and natural enemies on a brassica crop (August 1997).

1998

Briscoe, B.R. (1998) Report on preliminary investigations into the use of indigenous entomopathogenic nematodes for the control of insect pests of peri-urban agriculture in Kenya (August 1998).

Cooper, J., Dobson, H., Kamuyu, L., Karanja, P., Kibata, G., Mwaniki, S., Oduor, G., Ongaro, J. & Simons, S**.** Second Technical Report on pests, natural enemies and pesticide use on vegetable farms around Nairobi (1 April 1997 - 31 March 1998).

Dobson, H. M. Cooper, J. and Pete, S. Spray application using a lever operated knapsack sprayer - comparing the spray distribution using the standard conventional hand lance with a modified one which directs the spray upwards.

Oduor, G. & Karanja, P. (1998) Report on an exchange study tour visit to Zimbabwe (17 – 26 August 1998).

Marange, T. & Sithole, S.Z. (1998) Report on the exchange study tour visit to Kenya (2-11 February 1998)

1999

Kimani, D.K. (1999) Factors affecting blight (early and late) on tomatoes in contrasting agro-ecological zones in Kenya (March, 1999).

Cooper, J., Simons, S., Ongaro, J., Oduor, G., Dobson, H. & Kibata, G. (1999) Final Technical Report (1 April 1996 – 31 March 1999).

<u>Related but commissioned as Programme Development projects</u>

Lenne, J. (1999) Future priorities for pest management of vegetables in the peri-urban production system in East Africa (January, 1999).

Spence, N. (1999) Plant viruses on vegetables in peri-urban production systems in Kenya.

<u>Related but commissioned under a separate project</u>

Verkerk, R., Wright, D., Sithole, S., Kibata, G., Oduor, G., Musiyandaka, S. & Dobson, H (1999) Important natural enemies of vegetable pests in Kenya and Zimbabwe. Imperial College.

6c. Other Dissemination of Results:

1. Peri-Urban Vegetable Farmers Participatory Meeting (February 1998)
2. Peri-urban Vegetable Farmers Participatory Meeting (February,1999)
3. Farmer participatory workshop on Natural Enemies, Nakuru (March, 1999)

7. Project Logical Framework

Narrative summary	Objectively verifiable indicators	Means of verification	Important assumptions
Goal:			
Volume, quality and seasonal availability of food and crop products improved through the production of economic and physical losses caused by pests.	By 2005, crop losses in peri-urban vegetable production systems in target areas of Kenya reduced and sustainability increased		
Purpose:			
Improved methods for the control of pests and diseases affecting the quality and production levels of vegetables in peri-urban areas developed and promoted.	Demonstration field trials in two areas showing production of vegetables with increased level of natural mortality of pests, reduced levels of pesticide application, improved applicator safety and lower costs of production.	Final project report. A minimum of two publications submitted to internationally recognised journals.	Pests continue to be an important constraint to vegetable production
Outputs:			
Improved pesticide application systems which are cheaper and safer for the user in small-scale peri-urban vegetable production.	Field demonstrations carried out of improved techniques in comparison with prevailing farmer practices, including economic evaluation, by Oct 98	Project reports Scientific paper at end of project	Co-operation of farmers is gained.
A ranked list of potentially useful natural enemies and an evaluation of their effectiveness in natural suppression of important pests.	Natural enemies with most beneficial effect selected from the survey findings by Aug 97	Project reports	Taxonomic problems with indigenous natural enemies can be solved (e.g. the genus *Orius* has to be successfully reviewed).
An understanding of the effects of pesticides on natural enemy/pest dynamics in vegetable IPM systems.	Field trial results showing the effects of commonly used agrochemicals on indigenous natural enemies by Oct 98	Field trial reports	
Recommendations on the integration of natural enemies and selective pesticide application for control of key pests in vegetable IPM systems.	Strategies developed for integrated use of pesticides and biocontrol agents on 2 horticultural production systems by Dec 98	Project reports	
Effective demonstration of low-cost, safe and sustainable IPM methodologies	Farmer field demonstrations in two horticultural crops in each of two peri-urban locations showing the efficient production of vegetables with reduced dosage and frequency of pesticide application and enhanced levels of natural enemies, by Mar 99	Project reports	Farmer acceptance of new spraying methodologies and practices. Favourable weather conditions.

Activities:			
Measurement of the spray distribution and an assessment of operator exposure when applying pesticides.	Field trials carried out by Oct 98 to audit the fate of pesticides in typical horticultural spray applications	Project reports Reports of KARI Refereed paper	Suitable climatic conditions - absence of drought Farmers willing to collaborate
Survey of indigenous natural enemies and their impact in and around target crops. This will involve field trials to investigate their efficacy in the absence of pesticides.	Field surveys and trials of pest-suppression potential of natural enemies carried out by Aug 97	Project reports	Pests and their natural enemies appear in crops
Measurement of the impact and persistence of pesticides on natural enemies and pests in treated crops.	Persistence studies carried out. Impact studies carried out with the three most commonly applied pesticides in each of two horticultural crops by Oct 97	Project reports Refereed paper	Natural enemies and pests are present in sufficient abundance to conduct trials. Residue laboratories functioning properly
Development of pest management strategies which exploit and enhance the capacity of natural enemies to contain pest populations at acceptable levels, and which include judicious use of the most appropriate pesticides to correct imbalances	Theoretical integrated system developed for two horticultural crops by July 98	Project reports	
Formulation and testing of IPM guidelines based upon natural enemy conservation through selective pesticide use and application.	Field trials carried out in two horticultural crops by March 99. These trials will demonstrate successful integration of pesticides and natural enemies, and allow a reduction in pesticide usage while maintaining crop production and quality.	Reports on field trials	Suitable chemicals available for integration with natural enemy conservation

8. Contribution of Outputs

8a. What further research is necessary

The first phase of the project will be completed by end of March 1999. A submission for a second phase has been prepared and submitted to DFID through the Programme Manager in NR International. If agreed the second phase will build on the successes already achieved by the existing team of collaborators in order to develop practical and appropriate integrated pest management strategies which will be adopted by small-holder peri-urban farmers. An integral component of the proposal is the recommendations of an independent, NR International-funded consultant, Professor Jill Lenne, who undertook an intensive evaluation of the first phase of the project in December 1998 and January 1999. The team also agrees with the consultants' recommendation that a third phase of adaptive and promotional activities will be needed to achieve fully, Output 1of the Vision Framework and make a significant contribution to the Purpose.

The first phase of the peri-urban vegetable IPM project has achieved its objectives and has laid a good foundation for developing a 'basket of pest management options' for the production of peri-urban vegetables. The fact that natural enemy populations were particularly low where commercial pesticides were being used provides a good starting point to explore methods of enhancing natural enemy populations. Other areas include work with benign pesticides and an exploration of the potential role of clean and improved planting materials.

8b. Pathways whereby present and anticipated future outputs will impact on poverty alleviation or sustainable livelihoods.

Small-holder vegetable production provides an important source of employment, income generation and poverty alleviation for more than 200,000 households in rural areas around Nairobi. The major constraints in these peri-urban vegetable production systems are pests and diseases. Small-holder farmers still rely heavily on the use of pesticides to reduce the damage from pests and diseases, however, pesticides can result in residues in produce, induce resistance and be hazardous to human health and the environment, particularly beneficial natural enemies. 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 the general health of the urban population, especially low-income households, because fresh vegetables provide vitamins and energy to supplement the staple maize diet.

Uptake pathways for the outputs (current and future) of this project and others in the thematic cluster are already in place through the existence of farmer field schools in the peri-urban area, through active collaboration with NGOs including KIOF, and through more traditional extension services (Ministry of Agriculture & KARI). Additionally, in the second phase of this project, farmer-friendly publications will be produced and disseminated through a series of farmer participatory meetings.

8c. Stakeholder support and the need for a phase 2.

Farmers have given enthusiastic support throughout the project and as the end users of the technology it has always been a policy to maximise contact and discussions between researchers and the farmers themselves. Farmer participatory meetings have been well attended and, recognising the need for improved pest management methods, farmers have played a significant role in directing the research. A positive attitude to the project has always been forthcoming from the collaborators, including KARI, whose Director, Dr C. Ndiritu, recently wrote a letter of support to the Deputy Programme Manager, CPP. There has been international recognition of the value of the established collaborations including that between KIOF and CABI, and indeed, positive and friendly relationships at the scientific and personal levels have been a feature of the project. Clearly, the first phase of the peri-urban vegetable IPM project has achieved its objectives and has laid a good foundation and understanding of current pest management methods and their shortcomings. The complexity of the cropping system and the two types of production constraints (insects and diseases) requires a longer term approach than for a specific pest-crop interaction. A proposal for a DFID-funded phase II of the project is being submitted to the Programme Manager which would build on the research outputs from the first phase which are reported above.

Name and signature of author of this report and date signed.

J Cooper . ____________________