On-farm evaluation of integrated pest management of red spider mite in cut roses in Ethiopia

Final Report to the Ministry of Agriculture and Rural Development

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Ethiopia Netherlands Horticulture Partnership

Report 296

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1 Summary

Integrated Pest Management reduces the use of chemicals and therewith the impact of greenhouse horticulture on the environment. It improves working conditions and enables access of Ethiopian products on the world market. In response to such concerns the Ethiopian Horticulture Producers and Exporters Organization (EPHEA) has taken the initiative to develop a Code of Practice, of which Integrated Pest Management forms an integral part. The development of this code of conduct is supported through the Ethiopia-Netherlands Horticulture Partnership Programme.

On-farm trials at Ethiopian rose farms have been set up to investigate the efficacy of biological control under Ethiopian conditions, and to gain grower's acceptance of IPM. The experiments were started in November 2007, and are now reported until August 2008. Both the dry winter season with low night-time temperatures and the wet summer season with low radiation but higher night-time temperatures are covered.

Earlier versions of this report were submitted in May 2008 and September 2008. This final report is an update of the earlier reports, and essentially differs only in the longer period covered, the number of experiments described, and the robustness of the conclusions.

The results obtained in the on-farm trials so far lead to the following conclusions for Ethiopian rose horticulture:

1. Spider mite levels are substantially lower (down to complete absence) after release of a unique combination of *Phytoseiulus persimilis* and *Amblyseius californicus*, than if full chemical control is applied.
2. We do not have hard data from Ethiopian farms as yet, but farm managers indicate that integrated pest management results in production and quality increase.
3. Careful monitoring and intensive communication is essential to take the farm through the transition phase from chemical to integrated pest management.

We recommend to the Ministry of Agriculture and Rural Development:

1. Given the positive results of the on-farm trials, showing the efficacy of the biological pest management system, granting permits in the future for the commercial import of the predatory mites *Phytoseiulus persimilis* and *Amblyseius californicus* for the control of spider mite in rose is in our view be justified.
2. In a general sense, it is pointed out that the success of implementation of integrated pest management is enhanced by the commitment of the supplier and the grower alike.
3. Also in a general sense, environmental conditions may reduce the efficacy of the predators (e.g., extreme drought, low temperatures), which implies that a grower and the supplier should always be alert an be prepared to combine biological pest management with chemical pest management.

We thank all those who have co-operated in the research so far: farm owners, managers, scouts and other workers; the Ministry of Agriculture and Rural Development; the Ethiopian Institute of Agricultural Research, specifically the Plant Protection Research Centre; the College of Agriculture and Veterinary Medicine, Jimma University; the Ethiopian Horticulture Producers and Exporters Organization; the Netherlands Embassy at Addis Abeba; Koppert B.V.; and staff at Wageningen University and Research Centre.

The work was funded by WSSD funds of the Dutch Minsitry of Development Cooperation, under the umbrella of the Ethiopia-Netherlands Horticulture Partnership Programme; and by the Dutch Ministry of Agriculture, Nature and Food Quality, as a number of BOCI projects.

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2 Introduction

In 2006, 35 flower Ethiopian rose growers were interviewed to learn about their mayor pest and disease problems. Out of 35 farmers, 33 mentioned spider mite as the main problem (den Belder & Elings, 2007a). During a visit in January 2007 we collected insects at ten locations at several altitudes (from 1700-2600 masl). Insect species were identified by experts of the Phytosanitary Service in Wageningen, The Netherlands. Most mites collected at the various production sites were identified as *Tetranychus urticae* (common names: two spotted spider mite, red spider mite, glasshouse red spider mite and red mite). Two-spotted spider mite feeds on a wide rage of plants. It is an important pest of glasshouse crops and is commonly found on roses, beans carnations, chrysanthemums and many other ornamentals (see Annex 1).

Value chain analysis suggests that the costs of agrochemical inputs such as spraying constitutes a high proportion of the flower farming value chain. Over 92% of the spraying costs is for the purchase of agrochemicals (Global Development Solutions, 2006). A medium size farm under soil conditions uses an average of 23 different chemicals. Pesticides against mites (acaricides) account for 35-50% of the total cost the chemical pesticides. Efficacy of chemical control of spider mite is often disappointing, due to the fact that frequent application of pesticides results in development of pesticide resistance, as we already know in mites (Fergusson-Kolmes *et al*. 1991). In addition to that, it is difficult to reach the bottom sides of all leaves in the dense rose canopy properly when spraying chemicals. This leads to the survival of substantial amounts of mites.

Markets increasingly demand certified product with low chemical residues. Heavy use of agrochemicals can also be a threat to environment, and can affect workers' health. Acaricides belong to a variety of chemical groups which differ in their mode of action. Many acaricides belong to the highly hazardous groups according to the WHO (World Health Organization) classification of pesticides (WHO, 2005).

In response to these concerns the Ethiopian Horticulture Producers and Exporters Organization (EPHEA) has taken the initiative to develop a Code of Practice, of which Integrated Pest Management forms an integral part. The development of this code of conduct (including a plan for implementation) is supported through the Ethiopia-Netherlands Horticulture Partnership Programme.

Biological control of spider mite as a part of Integrated Pest Management can present a solution for some of the above mentioned problems. In many countries it has already proven to help growers to develop towards a more sustainable production system. Important natural enemies that have a proven track record for control of spider mite in roses are the predatory mites *Phytoseiulus persimilis* and *Amblyseius californicus* (see Annex 1).

Integrated pest management is a holistic approach to pest control in which multiple practices are implemented throughout the entire production period of the crop. Crop monitoring is the foundation of an IPM programme. Crop monitoring provides heightened awareness of pest presence, activity and control. It addresses the real needs of the crop, reduces pesticide use by eliminating unnecessary, routine applications and assures pesticides applied at the proper life-cycle stage to ensure effectiveness.

A large number of growers in Ethiopia acknowledge the need for adoption of Integrated Pest Management. With the endorsement of a wide range of stakeholders (growers, the Ministry of Agriculture and Rural Development, the Ethiopian Institute for Agricultural Research, the Ministry of Trade and Industry, the Ethiopian Horticulture Producers and Exporters Organization), it was decided in the course of 2007 to conduct on-farm trials to investigate the efficacy of biological control under Ethiopian conditions. The Horticultural Agency, which was established in 2008 by the Ethiopian Government, then joined as one of the stakeholders. Up-scaling in terms of acreage and crops were anticipated future developments.

This document reports on the 2007-2009 on-farm trials to investigate the efficacy of biological control of red spider mite in roses under Ethiopian conditions, and is submitted to the Animal and Plant Health Regulatory Division of the Ethiopian Ministry of Agriculture and Rural Development. Earlier versions of this report were submitted in May 2008 and September 2008 to the Ministry of Agriculture and Rural Development (den Belder & Elings, 2008b, c). This final report is an update of the earlier reports, and essentially differs only in the longer period covered, the number of experiments described, and the robustness of the conclusions.

Chapter 3 provides an overview of the set-up, results and conclusions of the on-farm trials. Our conclusions and recommendations are presented in chapter 4. These two chapters should suffice for those focused on the motives behind IPM and the research outcomes. Further in-depth information is provided in the annexes.

3 Field trials

3.1 Introduction: why on-farm trials?

On-farm trials at Ethiopian rose farms have been set up to investigate the efficacy of biological control under Ethiopian conditions, and to gain grower's acceptance of IPM. In a large-scale trial on a farm, researchers can document actual grower decision-making in the context of agronomic practices. To gain additional information, researchers can design complementary research to control the variable agronomic practices. Further research avenues have been elaborated in den Belder & Elings (2008a).

'Learning by doing' has been an important element of the used approach. The approach includes intensive observations, and relies on observation and monitoring of the state of the crop and the pests. This typically requires new ways of 'making things visible' and feedback loops between the formal research and informal research system:

- Regular field observation and measurement will be the basis for decision-making
- Record-keeping to make economic results transparent
- Exchange of information and experience among co-learners

In January 2007 it was proposed that demonstration trials are conducted at a limited number of farms based on the motto 'Small and solid'. Through visits by colleague farmers and study groups the results of the demonstration trials during the first phase would be disseminated. In later years, up scaling would take place – which has occurred by now.

Ten growers were visited in January 2007 (den Belder & Elings, 2007a). They had been selected on the basis of prior assumptions with regards to their willingness to participate in the trials, and variation in altitude. The final growers were selected on the basis of the following criteria:

- Willingness to participate in an IPM trial
- Presence of scouts
- Technically advanced
- Permitting students
- Willing to participate in study groups

It was considered important that rose farms at various altitudes participate in the trial, as each altitude knows its own climate with associated crop, pest and pathogen dynamics. At that time, trials have been started at five rose farms (Table 1; den Belder & Elings, 2007b).

On-farm trials at Ethio Highlands and at J.J. Kothari continue up to now, while trials at Lafto, Olij and Ziway have been discontinued for a variety of reasons:

- Lafto: A change of farm manager, who had a different risk perception during the transition phase from chemical to integrated pest management.
- Olij: Predator establishment was difficult due to low relative air humidity, and the trial crop was removed because of market considerations.
- Ziway: Chemical residues in the soil negatively affected the survival of the predators.

Although in itself, the discontinuation at these three farms was disappointing, the lessons learned were very valuable (see Chapter 4).

After on-farm trials at Ethio Highlands and JJ Kothari had been on-going for a full year, and had gone through all seasons, and after a number of lessons had been learned (see Chapter 4), at the request of the Ministry of Agriculture and Rural Development the on-farm trials were scaled up in terms of acreage at Ethio Highland, and in terms of number of farms (see Table 1). On-farm trials at Oromia Wonder, Dream Flower, Golden Rose and Herburg have started in December 2008, while on-farm trials at AQ Roses have started in May 2009.

Table 1. An overview of the farms at which the IPM on-farm trials have been conducted.

Name of farm	Location	Altitude (masl)	Start on-farm trial	End on-farm trail	Remark
Lafto	Addis Ababa	2300	2007/4	2007/12	Discontinued
Ziway	Ziway	1700	2007/11	2008/3	Discontinued
Olij	Debre Zeit	1950	2007/11	2008/1	Discontinued
Ethio Highlands	Sebeta	2100	2007/11		Up-scaling to complete farm
J.J. Kothari	Sululta	2600	2007/11		
Oromia Wonder	Holeta	2400	2008/12		
Dream Flower	Menagesha	2600	2008/12		
Golden Rose	Tefki	2000	2008/12		
Herburg Roses	Ziway	1700	2008/11		Gradual up-scaling at farm
AQ Roses	Ziway	1700	2009/5		

We report primarily on the long-standing on-farm trials at Ethio Highlands and J.J. Kothari, and briefly summarize the trials at the other farms.

A large number of partners collaborated in the on-farm trials:

- Farm owners, managers, scouts and other workers hosted the on-farm trials, took strategic decisions, were responsible for scouting and data collection, and executed the actual pest management.
- The Ministry of Agriculture and Rural Development has been the overall co-ordinating body and provided the import permits for the beneficials used in the trials.
- The Ethiopian Institute of Agricultural Research, specifically the Plant Protection Research Centre, has been responsible for the scientific evaluation of the trials, and requested the import permits for the beneficials used in the trials.
- The College of Agriculture and Veterinary Medicine, Jimma University has been involved in the research of the trials, through both staff and students.
- The Ethiopian Horticulture Producers and Exporters Organization has played an important facilitatory role with regards to process and stakeholders.
- The Horticultural Agency, which was established in 2008 by the Ethiopian Government, then joined as one of the stakeholders.
- The Netherlands Embassy at Addis Abeba has been supportive in many ways, at all times.
- Koppert B.V. has supplied the beneficials used in the on-farm trials, and has supplied extensive training and guidance.
- Staff at Wageningen University and Research Centre assisted in data processing and other supportive services.

3.2 Experimental set-up

Crops in the trial greenhouses were cleared from harmful chemical residues by changing from incompatible to compatible pesticides (see for compatible pesticides http://www.koppert.nl/Side_effects.html). The period this takes depends largely of the type of pesticides applied during the last 2-3 months.

Experiences elsewhere, and by now also in Ethiopia, have demonstrated the typical features of both species:

Phytoseiulus persimilis

- Needs spider mite to survive. The consequence is that its presence will be low if the spider mite presence is low.
- Develops rapidly if spider mite is present, and can bring down hot spots quickly.

- Is normally responsible for most of the pest management.
- May perform sub-optimal in harsh conditions (when temperatures are above 30°C and air humidity is low, this species struggles to control spider mites).

Amblyseius californicus

- Survives on various pests, and also on pollen. Consequently, it survives without the presence of spider mites.
- Develops slowly but steady.
- Performs better than *P. persimilis* under harsh conditions (and can still develop well at high temperatures e.g. 33°C and the lower limit is about 10°C)
- The idea is that this predator provides the 'basic control' to slow down beginning infection of spider mite

The experiments started of with the evaluation of *Phytoseiulus persimilis* (Koppert brand name: Spidex) versus a combination of *P. persimilis* and *Amblyseius californicus* (Koppert brand name: Spical). Plots were randomized, and a chemical control was incorporated in the trail (see Annex 2 for examples of experimental designs). Fairly soon, however, it was decided that one IPM was compared with a chemical control. Growers simply requested the best pest management approach, and it appeared difficult to realize treatment-specified population dynamics in small plots. The one IPM control was formed by a certain combination of *P. persimilis* and *A. californicus*, depending on the local circumstances.

The release schedules were planned as a standard schedule at the onset, but were later farm-specific adjusted according to the findings in the scoutings at the farms. If necessary, compatible acaricide applications were necessary to support the natural enemies during the first 2-3 months of the trial. The acaricides used for this purpose were Flora mite, Torque, Cascade and Nissorun.

3.3 Scouting

Scouts and farm managers have been trained in the application of natural enemies and the recognition and monitoring of mite and natural enemies in the crop.

Blocks were scouted on a weekly basis. From each block (A-D) 20 leaves were sampled: 10 from the skirt (the bottom part of the crop) and 10 from the stems (which carry the flowers). In week 9 the sampling system has been refined to obtain a more detailed view on the developments. Leaflets from the skirt and from the stems were taken separately (Table 2).

Observed data were processed as the percentage of leaflets in the sample with spider mite and predatory mites, respectively.

At E.T. Highland, both healthy and damaged leaflets were taken randomly throughout the block. At J.J. Kothari leaflets were also taken randomly, but only from places where spider mite damage (discolouration due to eaten cells) was observed. The chances of finding insects at Ethio Highland were therefore lower than at J.J. Kothari, and the figures at Ethio Highlands are likely to be lower than at J.J. Kothari. It is important to consider this difference when interpreting the graphs with scouting data.

The use of pesticides has been recorded for both the IPM as well as for the control block (pesticides applications as usual). Parameters recorded are:
- Date of application
- Pesticide trade name and active ingredient
- Quantity applied and
- Costs of the treatment.

Scouts were getting more and more experienced when carrying out the on-farm trials, and checked 'high risks places' as entrances, corners more carefully.

Table 2. Scouting schedules used at E.T. Highland and J.J. Kothari.

Up to week 8 - 2008	**Sample leaflets taken from skirt only**
Spider mites	
0	<5 mobile stages per leaflet
1	5 or more mobile stages per leaflet
Predatory mites	*Phytoseilus* and *Amblyseius* were monitored separately
0	no mobile stages per leaflet
1	1 or more mobile stages per leaflet

From week 9 - 2008	**Sample leaflets from skirt and from stems separately**
Spider mites	
0	0 mobile stages per leaflet
1	1-5 or more mobile stages per leaflet
2	5-20 mobile stages per leaflet
3	>20 mobile stages per leaflet
Predatory mites	Phytoseilus and Amblyseius were monitored separately
0	no mobile stages per leaflet
1	1 or more mobile stages per leaflet

3.4 Climate

Greenhouse environmental data have been recorded as these conditions can influence crop growth, and the population development of both spider mite and predatory mites. Daily values on temperature and relative humidity (24 h average, minimum, maximum) have been recorded.

The winter season is the dry season, whereas the summer season is the wet season. Due to the cloud cover, radiation levels are lower in summer than in winter. The summer season is more humid than the winter season. Average indoor temperatures are fairly stable throughout the year, however, night-time temperatures in winter are substantially lower than in summer, just as day-time temperatures are in winter substantially higher than in summer. Due to the cloud cover, summer temperatures do not rise very much.

The experiments were started in November 2007, and are reported until early 2009, depending on availability. Both the dry winter season with low night-time temperatures and the wet summer season with low radiation but higher night-time temperatures were covered.

Climate data are available for the following farms:

- Ethio Highland
- JJ Kothari
- Herburg

Further details can be found in Annex 5.

3.5 Communication

Each farm dedicated one special person to communicate the relevant data on a weekly basis by email to both Wageningen UR and Koppert Biological Systems.

The IPM Alliance is formed by all stakeholders: growers, MoARD, EIAR, Jimma, the Horticultural Agency and EHPEA. The Alliance meets on a periodic basis at one of the farms. Information and experiences are exchanged, to accelerate the learning process and to ensure interaction between the formal and informal research systems.

3.6 Results

3.6.1 General

Although the progress in time has been different at each farm, it can be concluded that the predatory mites have demonstrated their ability to control spider mite under Ethiopian conditions: since the large releases of beneficials during the transition period from chemical control to integrated pest management red spider mite populations were low to almost absent. Since *A. californicus* finally also appeared in the plots where only *Phytoseiulus persimilis* was introduced, it was not possible to compare the treatments of *P. persimilis* only with *P. persimilis + A. californicus* in combination. Treatments were changed to IPM versus chemical, which forms also the basis for this report.

The specific results of each farm will be explained below.

Annex 4 provides for a number of farms graphs with more detailed information on population development of spider mite (quantified through the number of infested leaves) and predatory mites.

3.6.2 Ethio Highlands

The trial started in week 46 (November 2007) in compartment 2 with rose variety Valentino. The actual release scheme of the predatory mites is given in Annex 3 . The trial can be divided in a number of phases.

The first phase covered December 2007 and January 2008, which was characterized by difficulties in establishing the biological system. This can be attributed to a number of causes:

- The actual introductions at the start were slightly lower than planned.
- Temperatures were quite low. It is known that low temperatures slow down the population development of spider mite, but even more that of the predatory mites. The time to bring under control a certain spider mite population is longer at lower temperatures. During the first months of the trial this led to insufficient control.
- Compatible acaricides (Floramite and Cascade) were sprayed weekly in an attempt to keep the pest under economical threshold levels. Unfortunately even these were not sufficiently effective, and the crop was heavily infested. Apparently the spider mite had started to develop resistance to these acaricides.

During phase 2, formed by the month of February 2008, corrective measures were taken to regain control. Two consecutive full cover sprays followed by some spot sprays were needed. Two other acaricides (Torque and Nissorun mixed) were used this time in order to break the resistance. At the same time three heavy weekly introductions of *P. persimilis* and *A. californicus* were made. In addition to that, improvements in the spray technique were made: increase of the spray solution from 1600 to 3000 liter per hectare, and spray at the end of the day instead of in the morning to avoid quick drying of the spray solution on the leaves. Soon after this, the predators started to develop and establish rapidly, leading to a quick reduction of the spider mite populations from week 9 onwards (see Figure 1).

Phase 3 started in March 2008. The corrective measures were effective, and the biological balances had been established. It is common, by the way, that the establishment of the biological balances takes a few months.

Important is to communicate well and frequently with growers, and to act promptly on the basis of scouting information.

Phase 4: Since then, small introductions of both predatory mites every two weeks are realized to maintain a small 'army' that attacks the spider mite in a very early stage. Actually no acaricides have been sprayed during the months of March, April, May June, July and August 2008. Figure 1 shows that **the spider mite presence in the biological treatments is (close to) zero, whereas the spider mite presence in the conventional treatment (with chemical spraying) is rising to 100%**. There is no difference between skirt (the lower leaf package) and stem (that produce flowers) in this regard.

Summary observation:
The rose crop is clean of spider mite in case of biological pest management, but strongly infected in case of chemical pest management.

As a consequence of the effective control of spider mite without the burden of regular sprays, the rose crop grows and produces very well.

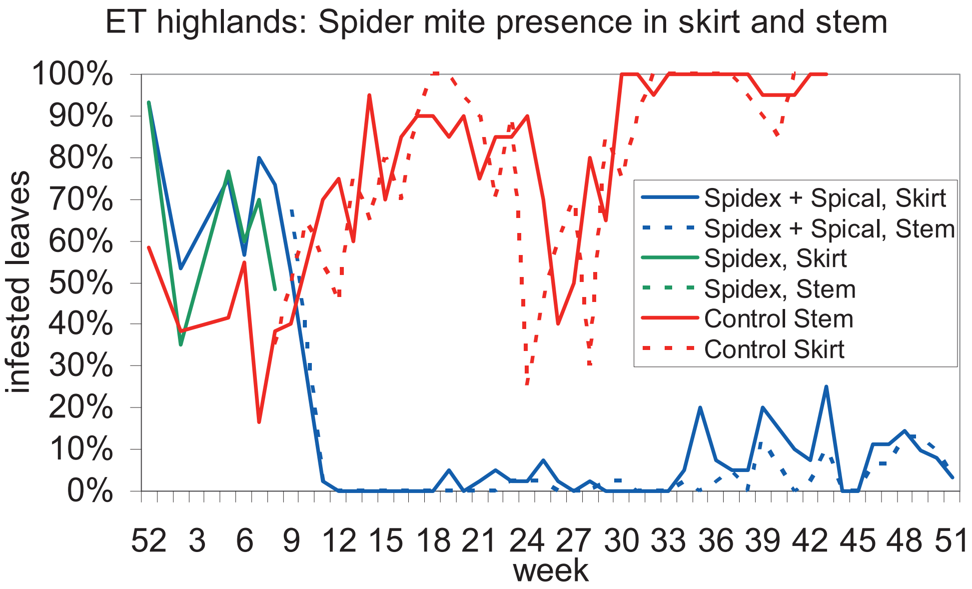


Figure 1. *Population development of spider mite in IPM house and control house in skirt respectively skirt and stem at Ethio Highland.*

From February onwards, the conventional greenhouse received weekly sprays with acaricides. Despite these frequent applications, the spider mite population increased and number of infested leaves fluctuated between 40 and 100%.

UP-SCALING

IPM was expanded to all 23 greenhouses of the entire E.T. Highland farm in October 2008. As the spider mite level varied, IPM was introduced to approximately half the number of greenhouses in week 40, and to the other greenhouses in week 41, during which the spider mite level was reduced with chemical pesticides.

The motivation to scale up from one greenhouse to all greenhouses was strong. The difference between the chemical and the IPM treatment was very distinct: whereas in the last months of 2008 the crop in the chemical treatment was relatively low and partially yellowing due to fytotoxicity caused by the pesticides, the crop in the IPM treatment is relatively tall and much greener compared to the rose crop in the conventionally treated greenhouse. The number of harvested stems was 10-20% higher, fewer stems were rejected, and stems were taller.

Lessons drawn from the first introductions late 2007 were, amongst others, that communication should be frequent and intense, and that the amounts of predators in the initial releases should be sufficiently high. The assumption was that with this knowledge, the risks of scaling-up would be low.

Having spoken with representatives from both the farm and the supplier, we can summarize the events during the months of October 2008 – February 2009 as follows:

- Parties involved had experienced early 2008 the risks involved associated with the introduction of IPM, however, believed that lessons learned were sufficient to minimize this risk in the phase of scaling up.
- Chemical pesticides were sprayed to reduce the number of plants infested with spider mites.
- Initially, predators of *Phytoseiulus persimilis* and *Amblyseius californicus* were introduced; to be followed by introduction of only *Phytoseiulus persimilis*; after which again predators of both *Phytoseiulus persimilis* and *Amblyseius californicus* were introduced.
- It was expected that the infestation with spider mite would reduce, followed by a reduction in predators and the establishment of a biological equilibrium at low infestation levels.
- Predator levels did not, or only slowly, increase. Spider mite levels remained high. Crop growth suffered in a number of greenhouses, and production decreased. In some instances, the crop had to be chopped to enable a fresh start.
- Following a visit by Alex Tetteroo from Koppert in mid-November 2008, the amount of predators released was increased, and *Amblyseius californicus* release was resumed. This resulted in an increase of predator levels and predator control over the spider mites.
- Following this, crop establishment improved, and production increased to the expected levels. Ultimately, production levels were higher than before the introduction of IPM.
- It is not clear what the determining factors have been in the variation among greenhouses. Variation among greenhouses is wide, and biological balances are very hard to quantify.
- After the situation recovered, and the crop became succulent again, powdery mildew came up. The increase of trips is dealt with by the present *A. californicus*.

This report does not deal with the issue of responsibility. However, it is very important to draw the following lessons from the experiences at ET Highland:

1. In the long term, IPM leads to a production increase because
    a. chemicals are not effective due to build-up of resistance against pesticides by the spider mites;
    b. due to less frequent chemicals phytotoxicity do not negatively affect the crop.
2. In the short term, there is an undeniable risk of reduced production.
3. Both point 1 and point 2 must be communicated extremely well, and acknowledged by all parties involved.
4. Balancing the long-term prospect and the short-term risk is of course at the discretion of the grower. It seems logical that the short and long term finances play an important role here, besides aspects such as a healthy working environment, the gain that is made by adhering to a Code of Conduct, etc.
5. Early warnings must be picked up.
6. Scaling up in advance of e.g. Valentine's Day, when profits are usually high, must be planned such that the period during which the biological equilibrium can establish is sufficiently long. This may last as long as 2-3 months.
7. Although again at the discretion of the grower, it might be advisable to scale up gradually – not all greenhouses at once. While scaling up, more experience is gathered that can be used in implementing IPM in the remaining greenhouses.
8. If possible, it is advised to start IPM in a young crop that is not yet infested with large numbers of pest insects. Perhaps control can be started in the propagation stage.

APHIDS

At the end of January 2008, aphids (*Rhodobium porosum*) appeared in small numbers in the IPM greenhouse. This aphid species is resistant against pirimicarb, which was initially used. But there are other compatible pesticides available to control, such as Plenum (pymetrozine). It took some time before the right chemical arrived on the farm. At this stage a very important lesson was learned: make sure the compatible pesticides needed for all relevant pests and diseases are in stock before the program is started. (See list in Annex 6). An on-farm experiment was conducted to manage aphids with *Aphidoletes aphidimyza* (predatory gall midge) and *Aphidius ervi* (parasitic wasp). However, it fairly soon appeared that these two predators were not able to sufficiently control the aphid population, after which the trial was discontinued.

3.6.3 J.J. Kothari

The trial started in week 46 (end of November, 2007) in greenhouse 3. The initial release scheme of the predatory mites is given in Annex 3. The trial can be divided in a number of phases.

In December 2007 and January 2008, the biological balances were establishing. Releases of beneficials were relatively high in this period, and the presence of spider mites was gradually decreasing. Establishment of the predatory mites was already visible in the crop three weeks after the start of the programme. Temperatures were relatively low in this period, even lower than at Ethio Highlands. For a two reasons, however, this did not lead to the difficulties in establishment of the biological system as observed at Ethio Highlands. As the starting levels of spider mite infection were relatively low, the amounts of introduced beneficials were sufficient. Also, the grower performed chemical corrections with only low amounts of compatible acaricides to keep the spider mite on a very low level.

From February 2008 onwards, biological balances had been established. Since then, small introductions of both predatory mites every two weeks are realized to maintain a small ‘army’ that attacks the spider mite in a very early stage.

As explained in chapter 3.3, leaflets were sampled only from places where spider mite damage (discolouration due to eaten cells) was observed. Infestation figures for J.J. Kothari are therefore higher than for Ethio Highland. Infestations show a peak in March, but have been declining strongly since then. There is no difference between skirt (the lower leaf package) and stem (that produce flowers) in this regard. During the warm period of the year, infestation levels were down to 10-20% in regions that show damaged leaves. If translated to a full crop, including the not-damaged regions, infestation levels are then approaching zero.

Towards the end of the year, when temperatures drop, the incidence of both spider mites and predators increase again. This is most likely a temperature effect, which negatively affects the predator population. The learning point here is that at locations with low winter temperatures, additional chemical pest management may be required.

Summary observation:
The rose crop is almost clean of spider mite in case of biological pest management.

Annex 4 provides detailed graphs with population development of spider mite and predatory mites in IPM house plus introduction numbers of predatory mites.

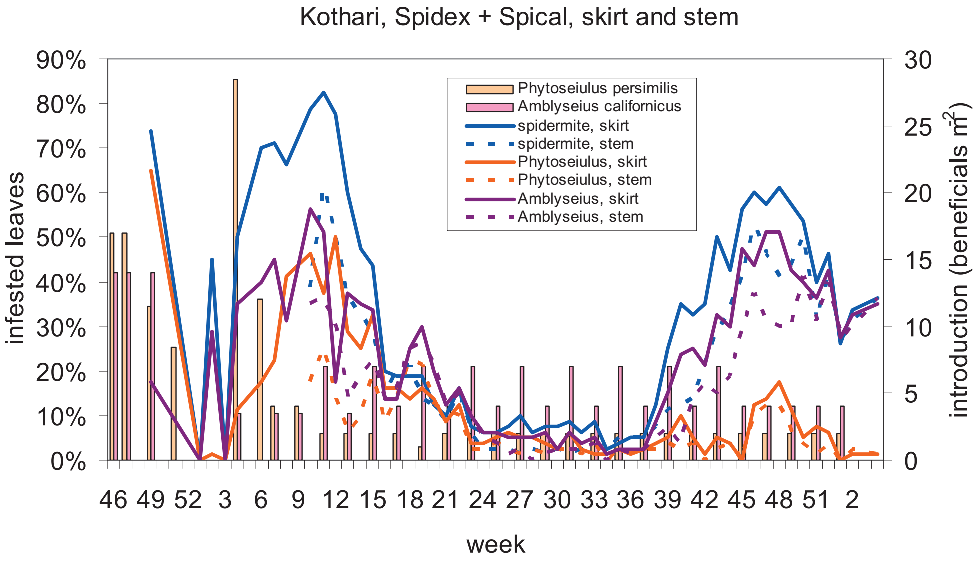
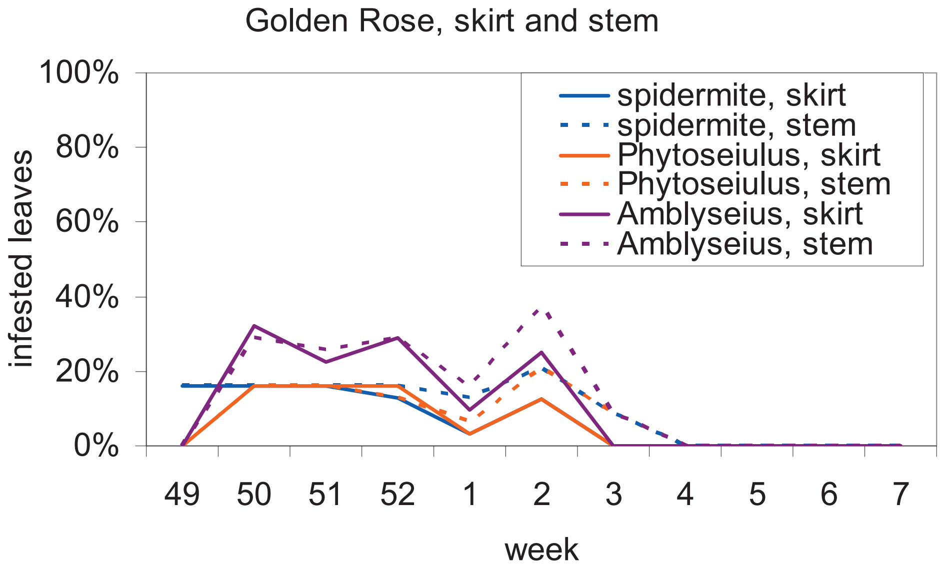


Figure 2. Population development of spider mite and predatory mites in IPM house plus introduction numbers of predatory mites (Phytoseiulus and Amblyseius) at J.J. Kothari.

3.6.4 Golden Rose

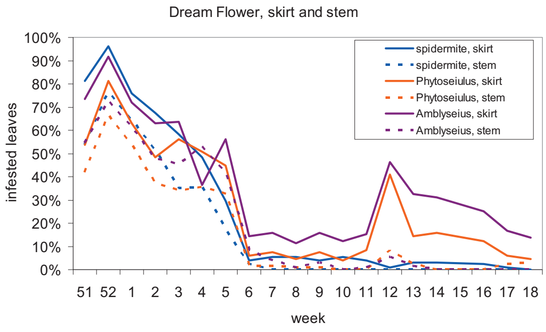
Trials at Golden Rose started in December 2008 in a one ha greenhouse. Spider mite levels were low from the onset, and quickly reduced to very low number after the introduction of predators. Only for a while, a few pockets with red spider mite remained along the sides of the greenhouse. By February 2009, the entire crop was clean.

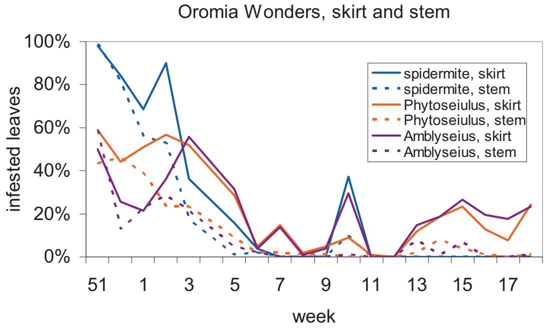


Golden Rose is an example where the introduction of IPM was successful. This was partly due to the lessons learned at previous farms. **The crop was clean of harmful residues, sufficient numbers of predators were introduced, and communication was well-organized.**

3.6.5 Dream Flower and Oromia Wonder

The farms Dream Flower and Oromia Wonder both belong to Holeta Roses PLC, and both introduced IPM in December 2008. Spider mite infestation levels were high at both farms in December 2007, but reduced over a period of approximately two months to low levels.



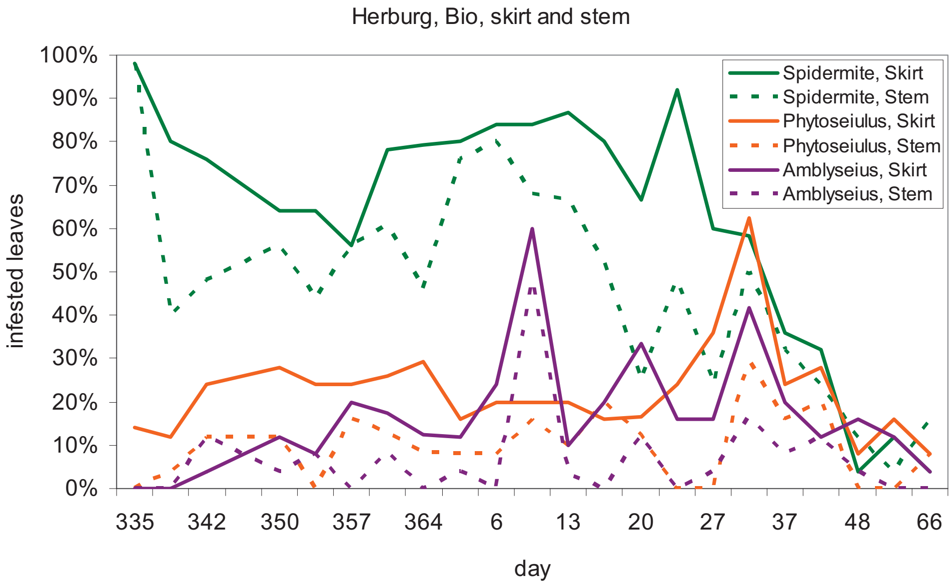


Summary observation:
At Golden Rose, Dream Flower and Oromia Wonder, the introduction of IPM was successful, without unexpected problems. Lessons learned were implemented.

3.6.6 Herburg

Herburg rose farm started with IPM in December 2008. The location of Ziway is particularly interesting because of the low air humidities that may occur.

It took a while before the level of spider mites reduced. The main cause – after checking many possibilities – was in the logistics. Transport of the predators from the airport to Ziway often took a full day, at high temperatures. This seriously affected the quality of the predators. Once the logistics had been improved, the introductions caused reduction of the red spider mite populations.



3.6.7 Crop Production

At the moment, detailed production data are not available as yet. However, at the IPM Field Day on June 28thN2008, farm managers of both ET Highland and J.J. Kothari indicated a 5-8% increase in number of harvested stems (Elings, 2008). In addition, stem quality (which is defined as stem length and stem thickness) has increased, which leads to a higher price per stem. It has even occurred that that stems are too long and thick! As at some point, a maximum price has been reached, there is a limit to acceptable stem length and thickness. Not using chemicals leads to an increased growth of the crop, which requires adjustment of crop management practices: more stems are required to benefit from the greater growth of the crop.

3.6.8 Predator efficacy

The on-farm trials have evaluated the combined effect of *Phytoseiulus persimilis* and *Amblyseius californicus*. The separate evaluation in small plots was abandoned very swiftly, as especially the growers simply desired the most effective control measure, and as it was not possible to isolate the predators in small plots. This was in line with the goal of the project: facilitate the introduction of an effective IPM measure in Ethiopian rose cultivation, which is not similar to experimentation with various predators. Now it has been shown that IPM against red spider mite in rose is possible, growers and suppliers will undoubltly try to further optimize the system.

The project has shown that under various conditions, a combination of *Phytoseiulus persimilis* and *Amblyseius californicus* can manage red spider mite in rose – this is the main outcome. The project can not quantify the efficacy of the separate predators, and it can not quantify parameters such as the minimum number of predators required under various conditions, the survival rate of the predators, etc. If such knowledge is required, then experiments at a research station are more suitable; on-farm trials are not best suited for this.

4 Conclusions and Recommendations

4.1 Conclusions

The results obtained in the on-farm trials performed over a period of nine months lead to the following conclusions for Ethiopian rose horticulture:

1. Spider mite levels are lower if integrated pest management is applied, than if full chemical control is applied.
2. The combination the predacious mites *P. persimilis* and *A. californicus* is an effective tool to control spider mite.
3. There is a wide range of farm, crop and pest management conditions to be dealt with before and after the onset of the introduction of beneficials.
4. Careful monitoring and intensive communication is essential to take the farm through the transition phase from chemical to integrated pest management.
5. These conditions can be met, and if these conditions are met, biological control can form the pillar of integrated pest management.

We do not have hard data from Ethiopian farms as yet, but farm managers indicate that integrated pest management results in production and quality increase.

4.2 Recommendations for practical implementation of IPM

A number of key factors contribute to the successful implementation of IPM at farm. The most important are:

1. The commitment and patience of staff at the farm (owner, managers, scouts)
2. The commitment of the supplier of beneficials
3. A good understanding of the biology of pests and predators. After first beneficials have been introduced, a population equilibrium between pest and predator will establish, but at a high level of number of insects of both pest and predator (which are released in high number). Only after some time, a population equilibrium develops at low numbers of pest and predator (see figures 1 and 2). Low introductions of predators are sufficient. It is important to realize that the predator population must first multiply before sufficient numbers are available to affect the red spider mite population.
4. Maximum communication between grower and supplier, on all aspects of the pest management
5. Clear expectations on both sides.

Before the introduction of beneficials, a number of conditions must be considered. These are described by our recommendations.

Experiences from the above described trials combined with those from IPM in cut roses in other countries have resulted in the following recommendations:

Grower

1. Develop a practical working manual that can be used by growers as a basis for their IPM approach, and includes standard procedures and a check-list of activities. Farm-specific procedures and activities can be based on this.
2. Develop a comprehensive plan with the supplier on how to control all pests and diseases in the crop. This plan should contain the introduction strategy for the predatory mites, and a list of compatible pesticides in order to avoid damage to the predatory mites or other beneficial insects (see Annex 6) The plan also includes arrangements with regards to expected performance, support and risk sharing.

3. Take sufficient stock of the pesticides needed before starting the IPM, to avoid that certain chemicals are not available at the moment they are needed.
4. Select one or more persons that can be trained for regular scouting.
5. Analyze the pesticides applied during the last three months before the first introduction of predators to make sure there are no toxic residues. If there is any doubt, make a trial introduction with *Phytoseiulus persimilis* in one bed with spider mite infection of spider mite. Approximately 10-14 days after this introduction, young predatory mites and their eggs can be found between spider mites, if the conditions are good.
6. Record all scouting data as well as the use of pesticides, and communicate this on a weekly basis to the biological control specialist that gives the advice.
7. Carefully choose the moment to start an IPM programme. It is always best to start in a young crop with a low population of spider mite (less than 20% of the leaves infested)[1]. With the present experiences, for Ethiopian conditions the best moment to start is at the end of the rain season, in September. Then, spider mite pressure is relatively low and air relative humidity is relatively high, which is advantageous for the predators. Preceding the first introductions of beneficials, all pests should be controlled with soft, selective pesticides. Similarly, downy mildew, which may increase during the rainy season, should be controlled with soft, selective fungicides.
8. Day-time temperatures are rising again (e.g., from below 25 °C to above 25 °C at Kothari), which is favourable to the development of the predators. Increasing levels of radiation (after overcast weather has ended) induce a strong crop that can better tolerate variation in pest pressure. Lower air humidity decrease the mildew risk.
9. During the first two months of the program, daily showering of soil or skirt of the crop can be helpful to boost the establishment of the predatory mites, however be aware of the consequences for mildew.
10. Logistics from the airport to the farm need to be well-organized. It is extremely important that the predators reach the farm without delay, and are transported swiftly and under cooled conditions.

Supplier

1. Use the practical working manual as a basis for the IPM approach, with regards to standard procedures activities. Farm-specific procedures and activities can be based on this.
2. Develop a comprehensive plan with the grower on how to control all pests and diseases in the crop. This plan should contain the introduction strategy for the predatory mites, and a list of compatible pesticides in order to avoid damage to the predatory mites or other beneficial insects (see Annex 6). The plan also includes arrangements with regards to expected performance, support and risk sharing.
3. Select with the grower the best moment to start an IPM programme, and explain the expected patterns in pest and predator presence during the first months of establishment.
4. Ensure the analysis of pesticides applied during the last three months before the first introduction of predators to make sure there are no toxic residues. Assist the farm manager in further decision making.
5. Ensure an adequate guidance of the pest management. Details depend upon the specific conditions at a particular farm, but serious attention has to be paid to training in scouting, and frequent communication with regards to any aspect that can be relevant to the success of the pest management. Periodic visits by personnel of the supplier to the farm is required.
6. Logistics need to be well-organized. Beneficials are living organisms, and should arrive to the farm as soon as possible, without delay during transport.

MoARD

1. Given the positive results of the on-farm trials, showing the efficacy of the biological pest management system, granting permits in the future for the commercial import of the predatory mites *Phytoseiulus persimilis* and *Amblyseius californicus* for the control of spider mite in rose is in our view be justified.

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[1] Take into account that after the use of traditional pesticides has been ended, spider mite population density will rise. This is dealt with by introduction of great amounts of predators (ensuring a biological balance at high population densities) and the corrective use of safe pesticides. If done well, the damage (loss of yield and quality) related to this infestation is minimal. This first period of the programme lasts approximately two to three months.

2. In a general sense, it is pointed out that the success of implementation of integrated pest management is enhanced by the commitment of the supplier and the grower alike (see recommendations to grower and supplier).
3. Also in a general sense, environmental conditions may reduce the efficacy of the predators (e.g., extreme drought, low temperatures), which implies that a grower and the supplier should always be alert an be prepared to combine biological pest management with chemical pest management.

4.3 The future

4.3.1 IPM of red spider mite

The on-farm trials were not designed to carefully optimize the introduction schemes. There will always remain questions:

- Are both Phytoseiulus persimilis and Amblyseius californicus needed, or is *only P. persimilis*? Is *P. persimilis* alone capable of pest management?
- What are the exact numbers of predators required in the introduction phase, and in later phases? To what extent do the populations maintain themselves?
- Do local predators move in to the greenhouse?
- Is additional chemical management needed?

These, and possibly more questions, will emerge from time to time. Each time again, the professional skills of both supplier and grower will be needed to make the optimum choices.

But the project has indicated that the principle of IPM works in rose in Ethiopia.

4.3.2 Other pests and diseases, and crops

After more than a year of on-farm trials at rose farms, IPM can be up-scaled. This development has to be specified in close collaboration with Ethiopian priorities, private sector interests, and chances to successfully implement the technology.

Up-scaling can be in three areas:

1. acreage
    i. larger area with biological control of spider mite on farms with existing trials
    ii. new growers with biological control of spider mite
2. other pests
3. other crops (e.g. indoor crops as other ornamentals and vegetables[2]).

Up-scaling in terms of acreage is already taking place, and is expected to continue. Now the IPM trials are successful, there may be a rapidly increasing demand for biological control agents. These will have to be imported by a variety of companies (*e.g.*, Koppert (The Netherlands), Real IPM (Kenya), Syngenta (USA), Biobee (Israel).

Biological control of spider mite is just the first step towards a more sustainable production system of cut roses. Other biological systems are available (and already widely used in other countries) to control other pests and diseases. The most important ones for the Ethiopian floriculture are listed in Table 3. So far also aphids, two other trips species have been found *Frankliniella schultzei* spp. *schulltzei* (Trybom) and *Megaluro trips sjostedti* and one whitefly species *Trialeurodes vaporariorum* (Westw.). These last species are known from interceptions by the Dutch Phytosanitary Service.

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[2] In the even further future, moving to outdoor vegetables and even other outdoor crops such as cotton, teff and oil seeds is envisaged.

We conclude that a more sustainable rose production implies more than a shift in farming practices. A change in training and knowledge about how to grow a good crop and sustainable pest management are inherent in the process. We further conclude that the introduction of Integrated Pest Management including biological control in the Ethiopian rose production will not be a matter of simply changing pesticide use or adopting technology. The growing confidence of growers to be involved in and contribute to the process of developing a more sustainable rose production in Ethiopia will be the key.

Table 3. Biological systems to be considered for up-scaling Integrated Pest Management in Ethiopian farming.

Pests	**Available biological solutions**
Aphids (various species)	Parasitic wasp *Aphidius ervi* Predatory gall midge *Aphidoletes aphidimyza*
Trips (*Frankliniella occidentalis*)	Predatory mite *Amblyseius swirskii*[3]
Whitefly (*Trialeurodes vaporariorum*, *Bemisia tabaci*)	Predatory mite *Amblyseius swirskii* Parasitic wasp *Eretmocerus eremicus*
Sciarid flies (Sciaridae)	**Predatory mite *Hypoaspis aculeifer*** **an entomopathogenic nematode *Steinernema feltiae***
Diseases	**Available biological solutions**
Soil borne diseases	*Trichoderma harzianum* T-22
Mildew (powdery, downy)	*Lactoperoxidase* system (Enzicur)[4]
Botrytis	*Lactoperoxidase* system (Enzicur) [2]

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[3] *Amblyseius swirskii* has been tried on some farms to investigate its effect against spider mite. However so far it has been outcompeted by *Amblyseius californicus*, which performs better on spider mite than *A. swirskii*. Also, the minimum temperature for *A. swirskii* is quite high.

[4] Enzicur is an effective agent. In some rose crops grown under Dutch winter conditions, however, this product has given phytotoxic reactions. When testing in Ethiopia, a difference during the sunny (strong growth) and rainy (reduced growth) season may therefore be observed.

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ANNEX I.

Some life table characteristics of two spotted spider mite, trips and predacious mites

	Life style	Minimum development temperature (°C)	Optimum temperature (°C)	Day degrees per generation	Relative humidity (RH)	Survival	Reference
Pest							
Tetranychus urticae	Mite that feeds on many crops	12	30°C (not above 40°C)	217	Reproduce faster at low humidity		Malais and Ravensberg, 2004 Kim, 2003
Predator							
Phytoseiulus persimilis	Only on tetranychid mites	11	15-25°C good predator (not above 30°C)	58* 91	Sensitive to low RH. At 27°C/40% high reduction of egg vitality and control At 21°C/40% no reduction of egg vitality or control RH < 60% has a negative effect on population growth, but note that the microclimate is often much more humid than measured above the crop.	2 weeks at 2.5°C	*Koppert, pers. comm. Morewood, 1992 Skirvin & Felton, 2003 Stenseth, 1979
Amblyseius californicus	Prefers two-spotted spider mites, eats also on other mites, trips and pollen	± 9-10	20-33°C Effectiveness at higher temperatures	±135	Requires higher RH. If RH <70% egg-hatching is strongly reduced Population development less depending on RH than Phytoseiulus	11 days at -5°C	Auger *et al.*, 1999, Hart, 2002 Raworth, 1994 Van Houten, 2008a,b
Amblyseius swirskii	Whitefly, trips and two spotted spider mites (is hampered by dense spider mite webbing)	15	25-28°C	not enough scientific data available	According to scientific research, A. swirskii does not tolerate low RH, but in hot & dry Spanish conditions it performs well.	Data not available	Malais & Ravensberg, 2004

Pests

Tetranychus urticae (two spotted spider mite) feeds on a wide range of different plants. The population growth depends on temperature and relative humidity, variety, age and quality of the crop. Of these temperature is the most important factor. This pest can spread through the crop in various ways. They migrate from heavily infested plants via the ground or via crop wires. They produce silk threads on which they are dispersed through air currents. As a result of rapid population growth and the frequent use of the same chemicals resistance can develop very rapidly in spider mites. Spider mite prefers temperatures around 30°C and low relative humidity however above 12°C populations can increase rapidly.

Predators

Phytoseiulus persimilis is an effective predator of spider mites particularly when temperatures are not too high (20-25°C). When temperatures are above 30°C this species struggles to control spider mites. A relative humidity lower than 60% has an adverse effect on the hatching of eggs. *P. persimilis* doe not perform well under dry, warm conditions. This predator gives sufficient control at 21°C and 40%. However modelling provides a powerful tool in gaining insights into the behaviour of predatory mites, still factors as optimal plant development are not included (Skirvin and Fenlon, 2003). This specialist predator is one of the most important biological control agents of spider mite, however often disappears because it only can reproduce on tetranychid mites (e.g. red spider mites).

Amblyseius californicus and *A. swirskii* can establish in crops on the other food sources also. *Amblyseius californicus* can still develop well at high temperatures e.g. 33°C and the lower limit is about 10°C. A relative humidity below 60% has a negative effect on population growth.

In sequence of preference for increasing temperatures:

- 15-25 °C: *P. persimilis*
- 20-33 °C: *A. californicus*, but slightly lower minimum temperature
- 25-28 °C: *A. swirskii*

In sequence of preference for increasing relative air humidities:

- Unknown %: *A. swirskii*
- Relatively medium humidity: *A. californicus*
- Relatively high humidity: *P. persimilis*

ANNEX II.

Initial trial designs

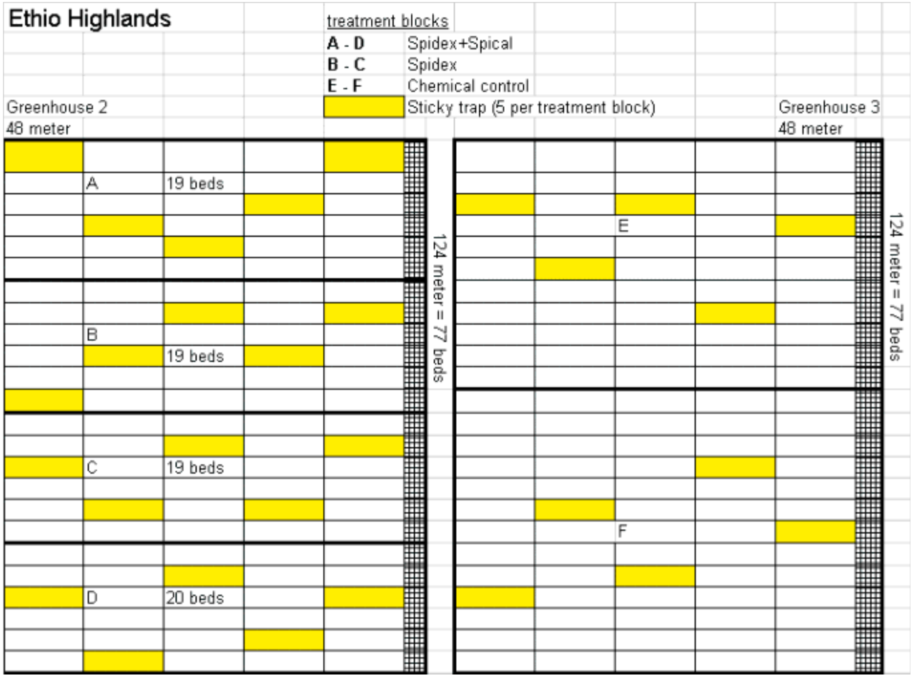

Figure II.1. The initial trial design at Ethio Highland (5300 m^2).

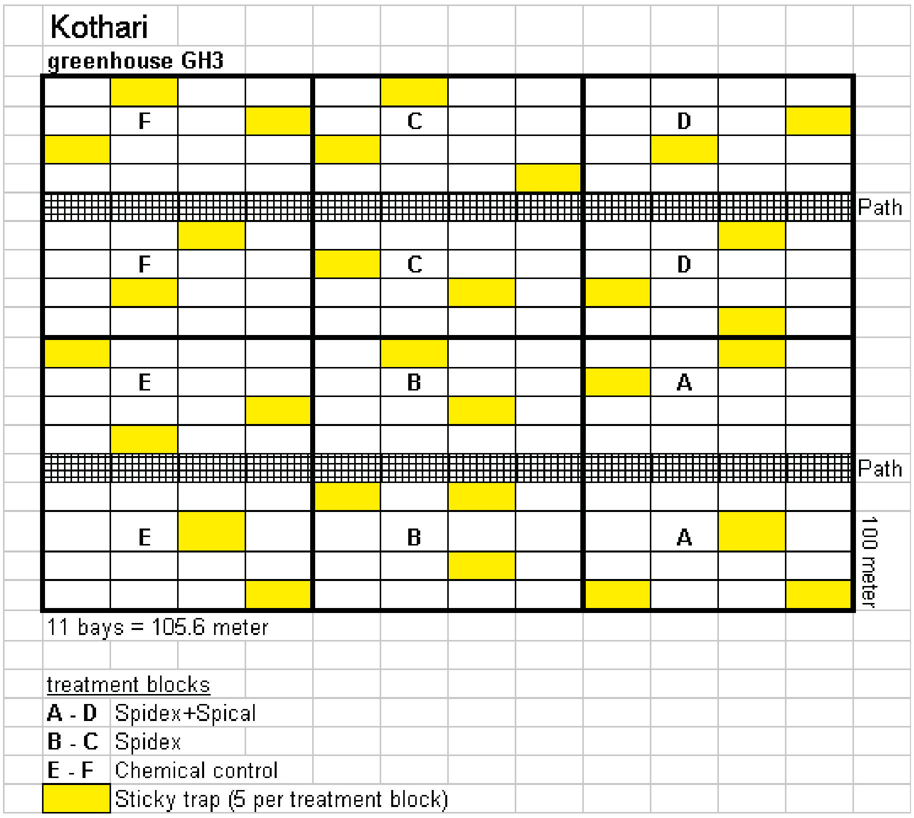

Figure II.2. The initial trial design at J.J. Kothari (7000 m^2).

ANNEX III.

Release schedules

The initial release schemes of predators for the Ethio Highland and J.J.Kothari farms (courtesy Koppert) give the actual releases so far, and planned releases for the future. The latter are indicative, and will be up-dated regularly, on the basis of pest, predator and crop observations.

Roses introduction schedule

Name: **Ethio-Highlands**

Area: **6,000**

KOPPERT BIOLOGICAL SYSTEMS

	Spidermite						Thrips			Thrips		
Product	**SPICAL**			**SPIDEX (318)**			**SWIRSKI**			**SWIRSKI**		
	Amblyseius Californicus			**Phytoseiulus persimilis**			**Amblyseius swirski**			**Amblyseius swirski**		
Per package	**25,000**			**2,000**			**250**			**50,000**		
Week #	per m2	insects	#	per m2	insects	#	per m2	insects	#	per m2	insects	#
46	9	50,000	2	3	16,000	8	0.5	375,000	3			
47	9	50,000	2	14	80,000	40						
48												
49	9	50,000	2	8	48,000	24						
50												
51				4	24,000	12	0.5	375,000	3			
52												
1												
2												
3												
4	4	25,000	1	20	120,000	60	0.5	375,000	3			
5	17	100,000	4	25	150,000	75				34.0	200,000	4
6	17	100,000	4	25	150,000	75						
7	17	100,000	4	8	48,000	24						
8												
9	17	100,000	4	4	24,000	12						
10												
11	8	50,000	2	2	12,000	6						
12												
13	8	50,000	2	2	12,000	6						
14												
15	4	25,000	1	2	12,000	6						
16												
17	8	50,000	2	2	12,000	6						
18												
19	4	25,000	1	1	6,000	3						
20												
21	8	50,000	2	1	6,000	3						
22												
23	4	25,000	1	1	6,000	3						
24												
25	8	50,000	2	1	6,000	3						
26												
27	4	25,000	1	1	6,000	3						
28												
29	8	50,000	2	1	6,000	3						
30												
31	4	25,000	1	1	6,000	3						
32												
33	8	50,000	2	1	6,000	3						
34												
35	4	25,000	1	1	6,000	3						
36												
37	8	50,000	2	1	6,000	3						
38												
39	4	25,000	1	1	6,000	3						
40												
41	8	50,000	2	2	12,000	6						
42												
43	4	25,000	1	2	12,000	6						
44												
45	8	50,000	2	2	12,000	6						
Total	212	1,275,000	51	135	810,000	405	1.5	1,125,000	9	34.0	200,000	4

Roses introduction schedule

KOPPERT
BIOLOGICAL SYSTEMS

Name: **Kothari**

Area: **7,000**
afd 1

	Spidermite						Thrips		
Product	**SPICAL**			**SPIDEX (318)**			**SWIRSKI**		
	Amblyseius Californicus			**Phytoseiulus persimilis**			**Amblyseius swirski**		
Per package	**25,000**			**2,000**			**250**		
Week #	per m2	insects	#	per m2	insects	#	per m2	insects	#
46	14	100,000	4	17	120,000	60			
47	14	100,000	4	17	120,000	60			
48									
49	14	100,000	4	12	80,000	40			
50									
51				8	60,000	30			
52									
1									
2									
3									
4	4	25,000	1	29	200,000	100			
5									
6				12	84,000	42			
7	4	25,000	1	4	28,000	14			
8									
9	4	25,000	1	4	28,000	14			
10						10			
11	7	50,000	2	2	14,000	7			
12									
13	4	25,000	1	2	14,000	7			
14									
15	7	50,000	2	2	14,000	7			
16									
17	4	25,000	1	2	14,000	7			
18									
19	7	50,000	2	1	6,000	3			
20									
21	4	25,000	1	1	8,000	4			
22									
23	7	50,000	2	1	6,000	3			
24									
25	4	25,000	1	1	8,000	4			
26									
27	7	50,000	2	1	6,000	3			
28									
29	4	25,000	1	1	8,000	4			
30									
31	7	50,000	2	1	6,000	3			
32									
33	4	25,000	1	1	8,000	4			
34									
35	7	50,000	2	1	6,000	3			
36									
37	4	25,000	1	1	8,000	4			
38									
39	7	50,000	2	1	6,000	3			
40									
41	4	25,000	1	1	8,000	4			
42									
43	7	50,000	2	2	14,000	7			
44									
45	4	25,000	1	2	14,000	7			
Total	147	1,050,000	42	126	888,000	454	0.0	0	0

ANNEX IV.

Population development of pest and predators

Ethio Highland

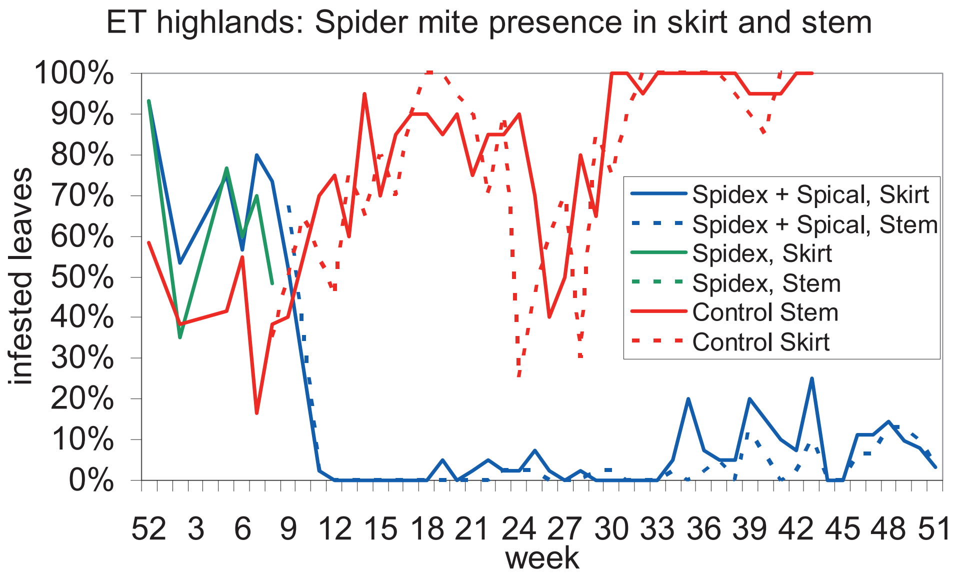

Figure IV.1. *Population development of spider mite in IPM house and control house in skirt respectively skirt and stem at Ethio Highland.*

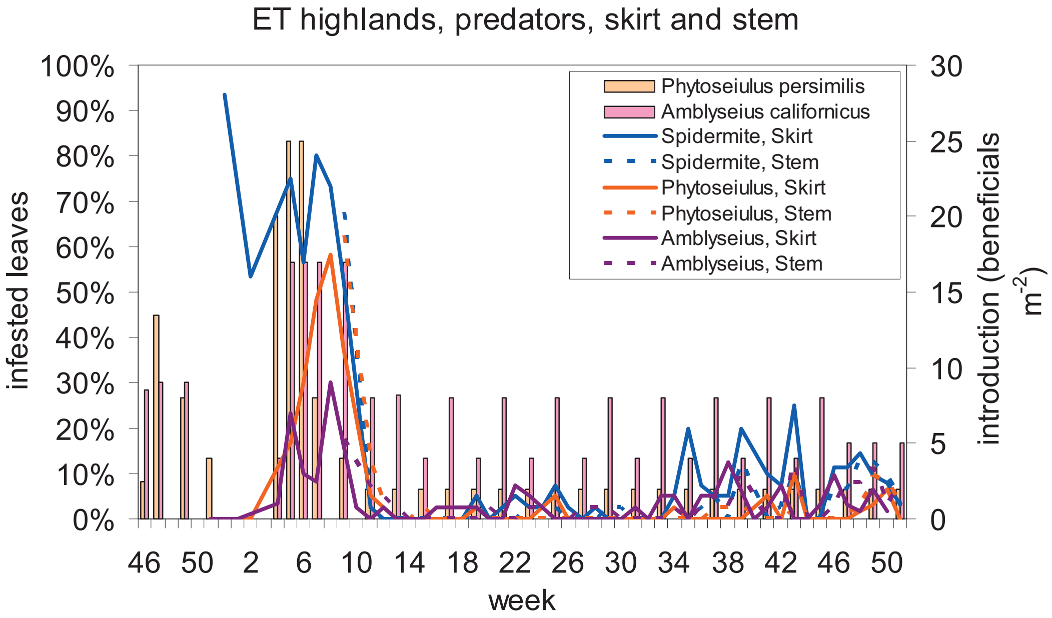

Figure IV.2. *Population development of spider mite and predatory mites in IPM house plus introduction numbers of predatory mites (Phytoseiulus and Amblyseius) at Ethio Highland.*

J.J. Kothari

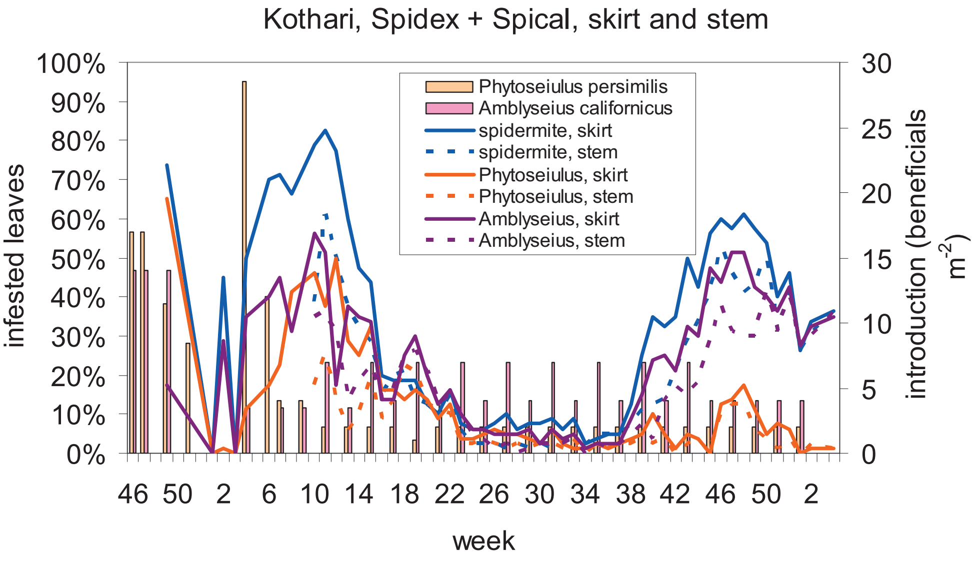

Figure IV.3. Population development of spider mite and predatory mites in IPM house plus introduction numbers of predatory mites (Phytoseiulus and Amblyseius) at J.J. Kothari.

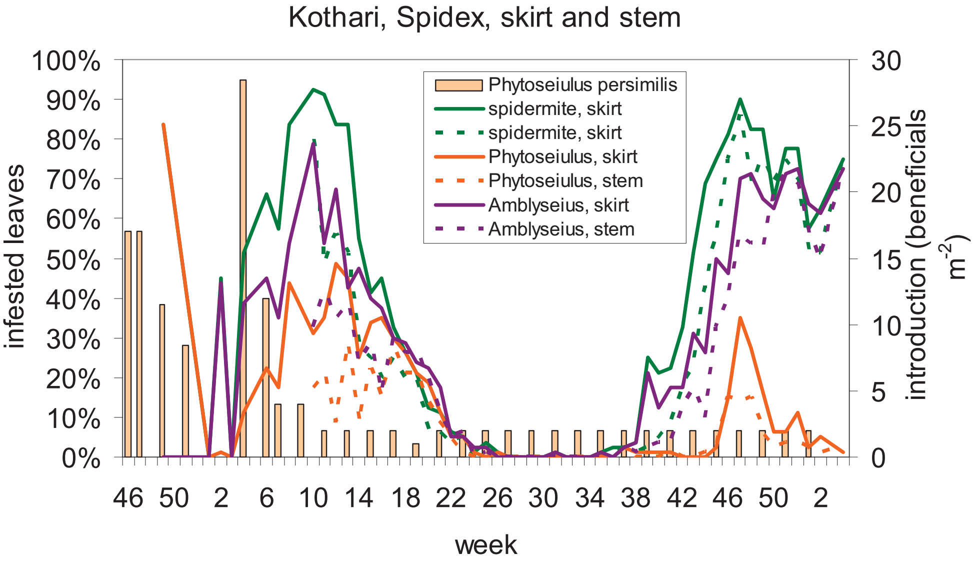

Figure IV.4. Population development of spider mite and predatory mites in IPM house plus introduction numbers of predatory mites (only Phytoseiulus) at J.J. Kothari.

ANNEX V.

Overview of environmental conditions

We present climatic data since the beginning of 2007, although the experiments started only at the end of November 2007. This is done to provide insight in the expected climatic trends.

The winter season is the dry season, whereas the summer season is the wet season. Due to the cloud cover in the summer season, radiation levels are then lower than in winter. The summer season is more humid than the winter season. Indoor temperatures are year-round approximately the same, however, minimum (night) temperatures are in winter substantially lower than in summer, just as maximum (day) temperatures are in summer lower than in winter. In other words, the difference between day and night-time temperatures is in winter much greater than in summer.

The experimental results so far cover the period of end November 2007 through August 2008. A few months more, and a complete year will have been covered. Already now, the IPM system has been evaluated under a wide range of climatic conditions, ranging from the dry winter season with low night-time temperatures to the humid summer season with less extreme temperatures.

Ethio Highland

- Daily inside average temperature varies between 15 and 20 °C, with slightly higher values in the first half year, and slightly lower values in the second half year. Minimum night-time temperatures vary between 5 and 15 °C for a large part of the year, except in the winter season, when values can approach zero, and the summer season, when values vary between 10-15 °C. Maximum day-time values vary between 35 °C in spring and 25 °C in summer. Average greenhouse temperatures are in summer slightly lower than in winter due to the lower radiation.
- Daily average relative air humidity in the greenhouse fluctuates between 60-70% in the dry winter and spring seasons to 80-90% in the wet summer season. Maximum night-time levels approach 100% all year through, but minimum day-time values vary between 40-60%.
- Relative air humidity depends on air temperature and the vapour pressure deficit (VPD) of the air. The latter is one of the factors that determines crop transpiration and is therefore relevant in crop physiological studies. The daily average VPD varies between 0.25 and 1 kPa. The values of the minimum (daytime) VPD are extremely low, and have to be taken with some caution (the measured RH may be too low).

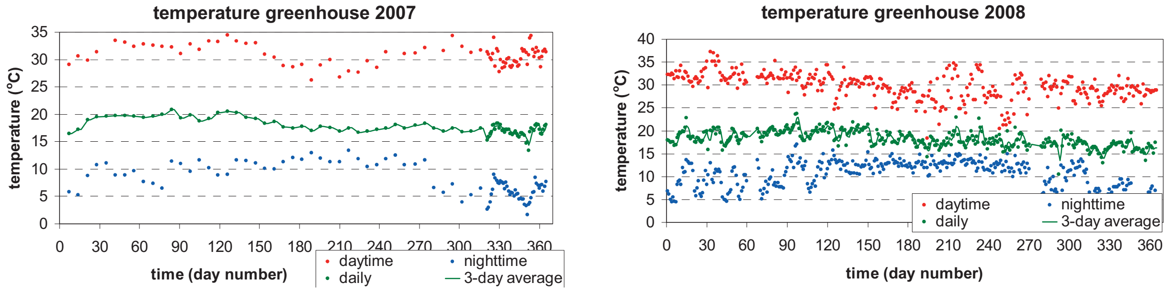

Figure V.1a. Greenhouse temperature for 2007 and 2008 (as far as available) at the ET Highland rose farm.

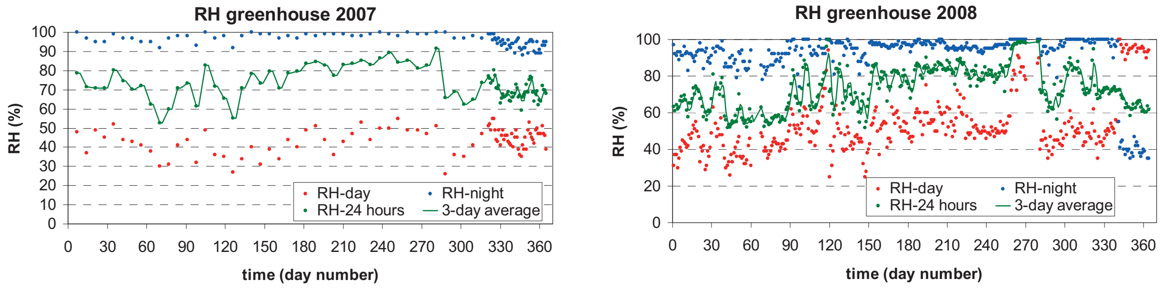

Figure V.1b. Greenhouse relative air humidity for 2007 and 2008 (as far as available) at the ET Highland rose farm.

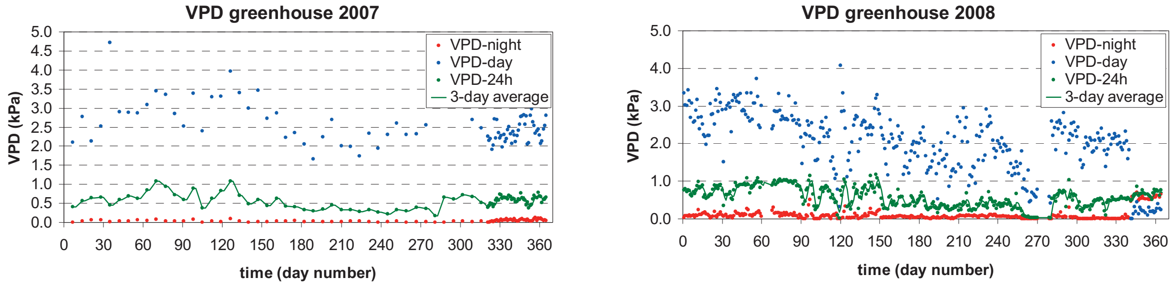

Figure V.1c. Greenhouse air vapour pressure deficit for 2007 and 2008 (as far as available) at the ET Highland rose farm.

J.J. Kothari

- Daily inside average temperature (at approximately 1.5 m) is fairly stable around 15 °C, with slightly higher values in the first half year, and slightly lower values in the second half year. Minimum night-time temperatures vary between 5 and 15 °C for a large part of the year, except in the winter season, when values can approach zero, and the summer season, when values are constant at 10 °C . Maximum day-time values are approximately 25-30 °C in winter, 20-25 °C in summer, and 25 °C in autumn.
- Daily average relative air humidity in the greenhouse fluctuates between 60-70% in the dry winter season to 90% in the wet summer season. Maximum night-time levels vary around 90% all year through, but minimum day-time values vary between 20-30% in the dry winter season to 50-70% in the wet summer season. A fogging system is used at the farm to prevent further lowering of relative air humidity.
- Relative air humidity depends on air temperature and the vapour pressure deficit (VPD) of the air. The latter is one of the factors that determines crop transpiration and is therefore relevant in crop physiological studies. The daily average VPD varies between 0.4 and 1 kPa in the wet winter season and is approximately 0.1-0.2 kPa in the dry summer season.

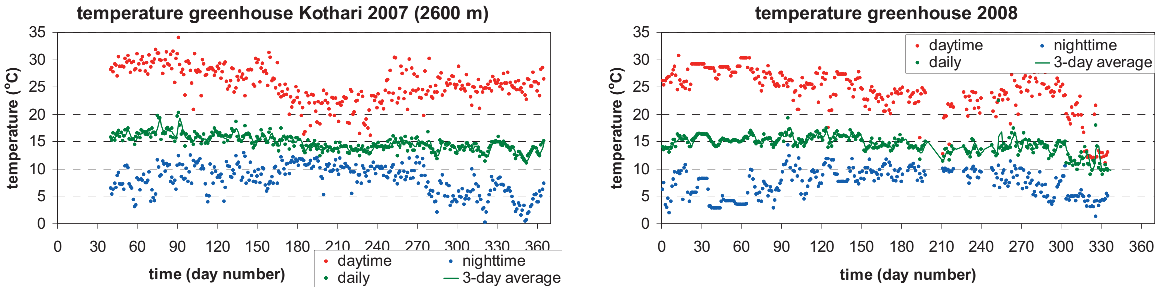

Figure V.2a. Greenhouse temperature for 2007 and 2008 (as far as available) at the Kothari rose farm.

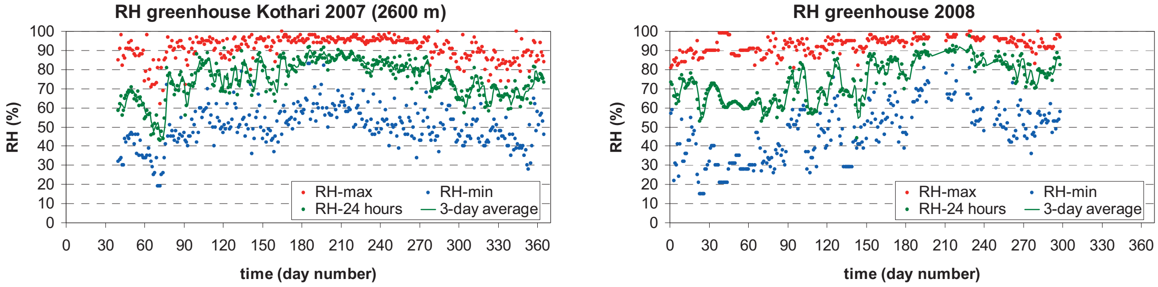

Figure V.2b. Greenhouse relative air humidity for 2007 and 2008 (as far as available) at the Kothari rose farm.

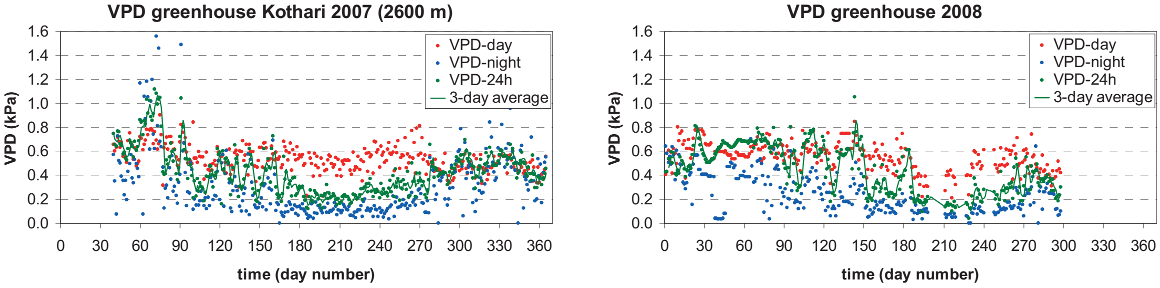

Figure V.2c. Greenhouse air vapour pressure deficit for 2007 and 2008 (as far as available) at the Kothari rose farm.

Herburg

Environmental data from Herburg at Ziway are known for only a short period. Ziway is known as a dry site, where air humidities can be very low.

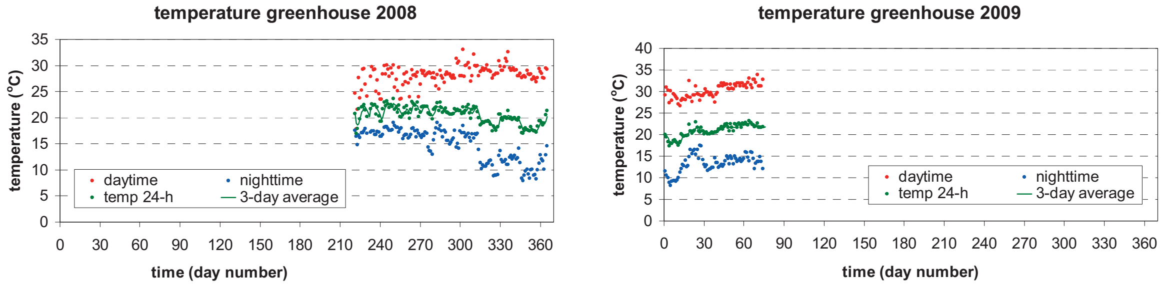

Figure V.3a. *Greenhouse temperature for 2008 and 2009 (as far as available) at the Herburg rose farm.*

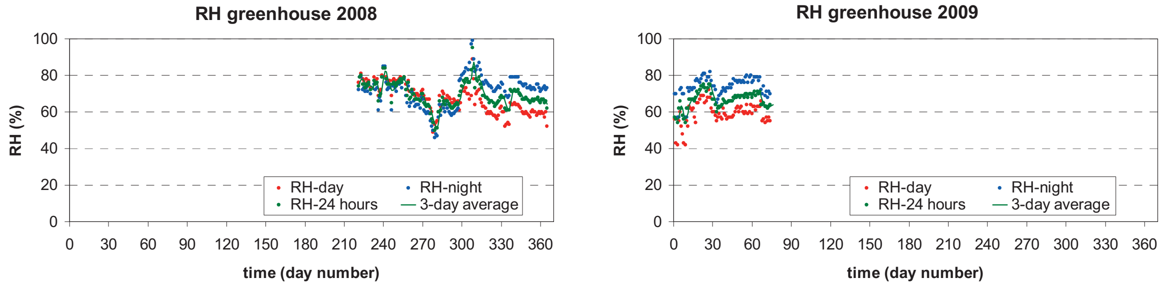

Figure V.3b. *Greenhouse relative air humidity for 2008 and 2009 (as far as available) at the Herburg rose farm.*

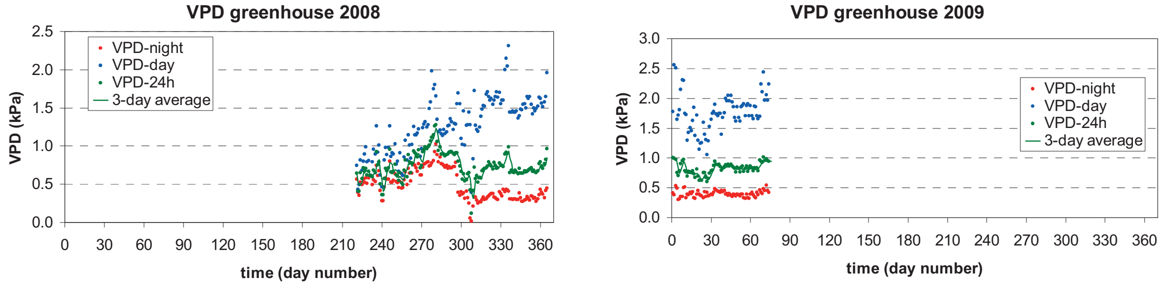

Figure V.3c. *Greenhouse air vapour pressure deficit for 2008 and 2009 (as far as available) at the Herburg rose farm.*

Outdoor environment

- Daily outside global radiation varies between approximately 100 J cm^{-2} d^{-1} in the rainy summer season and 275 J cm^{-2} d^{-1} in the dry winter season. Values are fairly similar, except for ET Highland in the winter season, when relatively low values were recorded.
- The temperature is strongly related to the altitude. Ethio Highlands and Kothari are located at 2300 and 2600 masl, respectively. Daily outside average temperature at Kothari, the highest location, is at most 5 ^{o}C lower than at Ethio Highland.
- It is not entirely clear whether minimum night-time and maximum day-time values are absolute values, or averages over the period. In any case, the sequence of minimum night-time values corresponds with the altitude, with Kothari at the highest altitude having the lowest temperatures.
- The maximum day-time values are at first sight not entirely logical, as Kothari (higher altitude) has a lower temperature than Ethio Highland (lower altitude). On the other hand, the relation between location and daytime temperature is influenced by other factors than altitude.

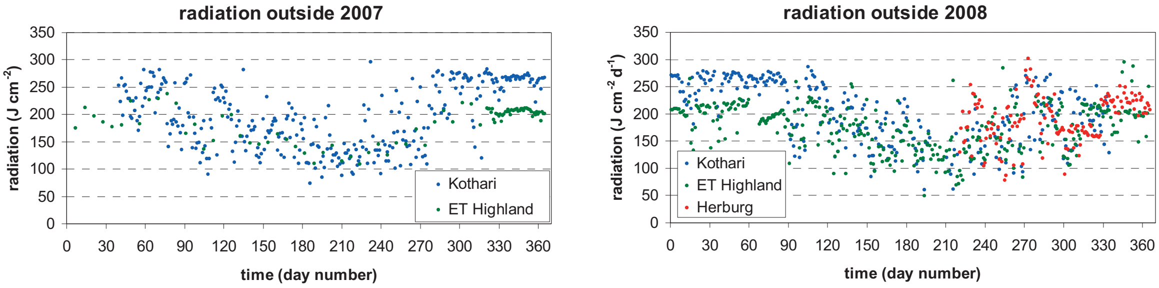

Figure V.4a. Global radiation outside the greenhouse for 2007 and 2008 (as far as available) at the Kothari and Ethio Highland rose farms.

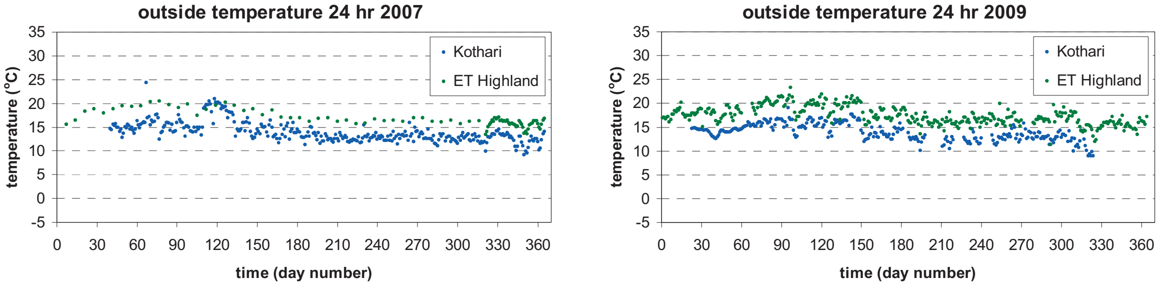

Figure V.4b. Average daily temperatures outside the greenhouse for 2007 and 2008 (as far as available) at the Kothari and Ethio Highland rose farms.

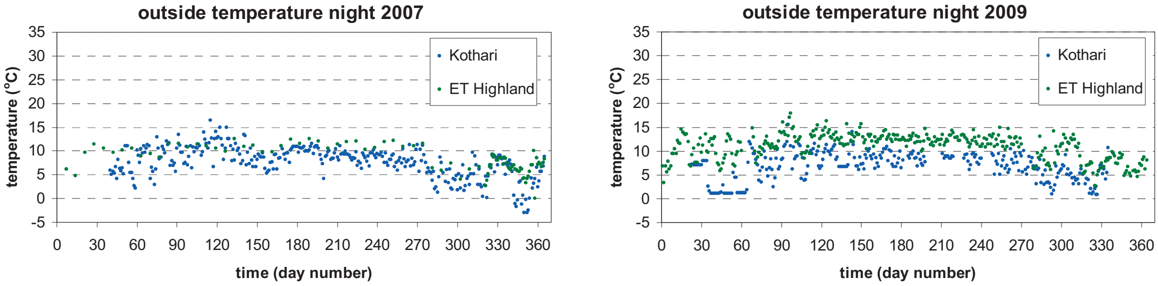

Figure V.4c. Minimum day-time temperatures outside the greenhouse for 2007 and 2008 (as far as available) at the Kothari and Ethio Highland rose farms.

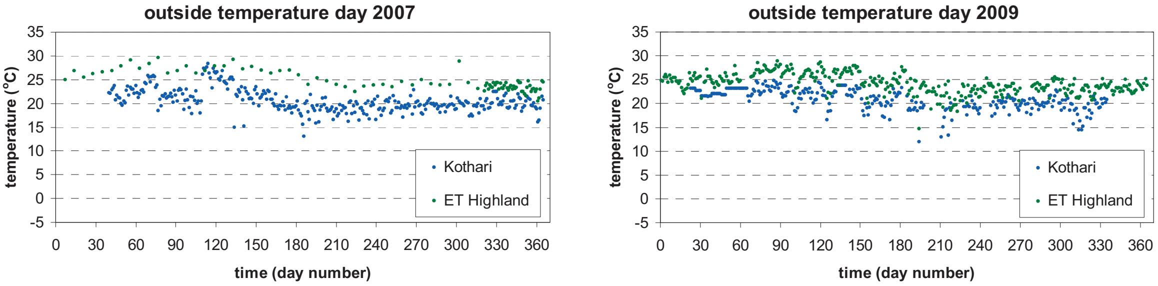

Figure V.4d. *Maximum day-time temperatures outside the greenhouse for 2007 and 2008 (as far as available) at the Kothari and Ethio Highland rose farms.*

ANNEX VI.

Overview of compatible pesticides per pest and disease in cut roses

Detailed information about side effects of pesticides on beneficials can also be found on www.koppert.com

Pests • active ingredients (default application = spray; other methods specified– most common trade name	**Diseases** • active ingredients – most common trade name
Spider mite • fenbutatin oxide – Torque • hexythiazox – Nissorun • clofentezine – Apollo • azocyclotin – Peropal • bifenazate – Floramite • flufenoxuron – Cascade • tetradifon – Tedion Aphids • pymetrozine – Chess, Plenum • pirimicarb – Pirimor • thiamethoxam – Actara • acetamiprid – Mospilan, Golan • imidacloprid (drench) – Confidor Caterpillars • Bacillus thuringiensis • indoxacarb – Avaunt • lufenuron – Match Trips • spinosad – Tracer • acetamiprid – Mospilan • lufenuron – Match Whitefly • pymetrozine – Chess • acetamiprid – Mospilan • buprofezin – Applaud • pyriproxifen – Admire • imidacloprid (drench) – Confidor Root nematodes • azadirachtin (drench)	Powdery mildew • triadimenol – Bayfidan • triadimefon – Bayleton • dodemorph acetate – Meltatox • bupirimate – Nimrod • flusilazol – Nustar • mycobutanil – Systhane • penconazole – Topaz • azoxystrobin – Ortiva • trifloxystrobin – Flint Downy mildew • fosethyl-aluminium – Aliette • chlorothalonil – Daconil • propamocarb hydrochloride – Previcur • kresoxim-methyl – Stroby • metalaxyl + mancozeb – Ridomil • mancozeb – Dithane Botrytis • pyrimethanil – Scala • tolylfluanid – Euparene-M • iprodione – Rovral