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Development of Integrated Pest Management in Greenhouse Cut Roses (in the Netherlands)

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ABSTRACT

Generalist predatory mites were tested for controlling mites and small insects in greenhouse grown cut roses. *Euseius ovalis*, *Amblyseius swirskii*, *Typhlodromalus limonicus*, *Amblyseius andersoni* and *Iphiseius degenerans* were found to establish persistent populations year-round. They were associated with two-spotted spider mites, greenhouses whiteflies and/or western flower thrips. No effect on mealybugs could be demonstrated. Current IPM practices as applied by Dutch rose growers in the year 2008 are briefly described.

Keywords: *Amblyseius andersoni*, *Amblyseius swirskii*, biocontrol, *Euseius ovalis*, Phytoseiidae, predator, spider mite, thrips, whitefly
Abbreviations: IPM, Integrated Pest Management

CONTENTS

INTRODUCTION

The two-spotted spider mite (*Tetranychus urticae* Koch), the western flower thrips (*Frankliniella occidentalis* Pergande) and the greenhouse whitefly (*Trialeurodes vaporariorum* Westwood) are the most important pests in Dutch greenhouses.

Potentially, greenhouse cut roses form an ideal crop system for year-round Integrated Pest Management (IPM). In the Netherlands, a rose crop is typically grown for 3 to 5 years, temperature never falls below 19°C and artificial light is supplied maintaining a minimum of 5000, preferably 15,000 lux. While only the flowering stems are harvested, the main part of the foliage remains, allowing predator populations to persist.

In spite of the potential for biocontrol, until the early 1990's the vast majority of Dutch growers did not even consider it. Social criticism on pesticide use increased, and roses were pilloried as an excessive consumer of pesticides second only to chrysanthemums. According to a survey conducted in 1992, the greenhouse segment of Dutch horticulture, representing less than 1% of the agricultural area, accounted for 18% of the total amount of insecticides used (LNV 2001). The Dutch Ministry of Agriculture, Nature and Food launched a program to reduce the dependence on chemicals in plant protection (LNV, 1991- Meerjarenplan Gewasbescherming). The decisive criterion has shifted from "kilograms active ingredient applied" via "emission" towards "environmental impact". Taking 1998 as a reference, a 95% reduction by the year 2010 was imposed on the whole agricultural sector (LNV 2004). Abandoning soil disinfection and applying IPM were considered important methods to achieve this goal. The Ministry stated that 90% of the glasshouse growers should have adopted year-round IPM by the end of 2005 (LNV 2001). For this purpose, various research, demonstration and stimulation projects were financed (De Lauwere *et al*. 2004).

In spite of these efforts, only 15% of the rose growers used year-round IPM in 2003. Crop protection specialists signalled a stagnation. It was put forward that bringing about a mentality change among growers was not enough, but that more effective IPM scenarios should be developed. In this year, the research stations of Naaldwijk, Aalsmeer and Boskoop initiated efforts to discover and test better control agents. Generalist predatory mites (phytoseiids) were chosen as the natural enemies to focus on. Prolonged populations of predators were sought rather than working with repeated introductions as was the common practice up till then. Eva-

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luation in the target environment was chosen as a selection method rather than determining various bionomics in the laboratory.

In 2008, somewhat over 50% of the rose growers practiced IPM, and generally a more positive attitude towards biocontrol has become evident. The following factors have contributed to this development (see http://www.ctb-wageningen.nl/ for chemical registration in the Netherlands):

- expired registration of broad spectrum and persistent pesticides, for example dienochlore (December 2001), acephate (January 2003), carbofuran (December 2007), methomyl (March 2009), fipronil (June 2009),
- availability of new selective acaricides (bifenazate, 2003) and insecticides (spinosad, 2002; lufenuron, 2006; neonicotinoids since 1994; indoxacarb, 2003; methoxyfenozide, 2005; pymetrozine, 2003; flonicamid, 2008),
- availability of new (*Amblyseius swirskii* Athias-Henriot, 2005 and *Amblyseius andersoni* Chant, 2007) or cheaper (*Neoseiulus californicus* McGregor, 2007) predatory mites.

RESEARCH ON IPM IN ROSES

An inventory of beneficials was carried out in 2003 by collecting leaf samples from 40 rose greenhouses using either integrated or chemical pest management. The predatory mites *Phytoseiulus persimilis* Athias-Henriot, *Neoseiulus cucumeris* Oudemans, *N. californicus*, *Amblyseius barkeri* Hughes, *A. andersoni*, *Iphiseius degenerans* Berlese and *Amblyseius alpinus* (=*A. aurescens*) Schweizer were found associated with spider mites. In outdoor rose crops, *N. californicus*, *Amblyseius rademacheri* Dosse, *Kampimodromus aberrans* Oudemans, *A. andersoni* and *Euseius finlandicus* Oudemans were collected (van der Linden 2003). The (sub-) tropical species *A. swirskii*, *Euseius scutalis* Athias-Henriot and *Euseius ovalis* Evans were obtained from the University of Amsterdam (Nomikou *et al*. 2001).

In 5 successive years (2003–2008), available species were tested in experimental glasshouses on full grown rose crops with mixed pest populations (spider mites, thrips, whiteflies). In smaller compartments, selected predator species were studied in interaction with single pests (Pijnakker 2005). In commercial greenhouses, predator populations were monitored over prolonged periods. In the latter case, mixed predator populations were often found, originating from artificial introductions, contamination of plants or other materials that were brought in or occurring spontaneously.

Amblyseius barkeri, *E. scutalis*, *E. finlandicus* and *N. cucumeris* failed to establish on rose. The generalist predators *E. ovalis*, *A. swirskii*, *Typhlodromalus limonicus* Garman & McGregor, *I. degenerans* and *A. andersoni* could maintain permanent populations throughout the year, provided that enough food was available. The specialists *P. persimilis* and, to a lesser extent, *N. californicus*, completed successive generations, as long as spider mites were present. After having destroyed the pest colonies, *P. persimilis* disappeared first and *N. californicus* a few weeks later.

Short day conditions in winter do not appear to be a problem. Artificial heating and light clearly prevented the induction of diapause. Hot spells in summer (temperature > 30°C and relative humidity < 50%) may decimate predator populations. After recurrence of moderate conditions, they recovered without being reintroduced, but meanwhile were lagging behind the pest.

In commercial greenhouses, predatory mites persisted throughout the year as long as broad spectrum pesticides could be avoided. IPM advisors have difficulty monitoring and evaluating predator introductions since most species can not be told apart in the field. Often the crops were found to house other predator species than the grower believed they had introduced. November until February appeared to be a critical period, apparently because of absence of prey. Surprisingly, even a specialist like *P. persimilis* sometimes showed up without being introduced.

As temporary or local absence of prey seems to be the main problem for the predators, methods are researched to provide them with alternative or additional food. Artificial diets, pollen or harmless mites may be a substitute source of protein. Pure pollen of cattail, corn and castor bean as well as bee collected pollen of *Cistus* sp. were found to favour the development of *E. ovalis* and *A. swirskii*, being the most promising predators for greenhouse grown roses at present.

Spider mites

Phytoseiulus persimilis continues to be the best predator for quickly eliminating hotspots of spider mites (Sabelis and van de Vrie 1979; Gough 1991). Soon thereafter, the predator dispersed and became undetectable. Populations of *N. californicus* tended to persist a bit longer, but only for a few weeks (Pijnakker *et al*. 2007).

Whitefly

The effect of 3 phytoseiids (*E. ovalis*, *A. andersoni* and *A. swirskii*), introduced alone or in combination with the parasitoid *Encarsia formosa* Gahan, on greenhouse whitefly was evaluated (Pijnakker *et al*. 2007). *Euseius ovalis* showed the strongest numerical response to trends of the whitefly populations. However, we did not succeed in controlling whitefly populations with predators only. The phytoseiids seem to avoid leaves with accumulated honeydew. The parasitoid maintained a high parasitization level throughout the year.

Thrips

Amblyseius swirskii and *E. ovalis* appeared to be good predators for controlling Western Flower Thrips (Pijnakker and Ramakers 2008), noticeably better than *A. andersoni* and the standard *N. cucumeris*. However, even high predator density did not completely prevent periodical cosmetic damage on the flower buds and petals. In the compartments with the weaker predators, *N. cucumeris* and *A. andersoni*, severe distortion of flower buds occurred.

Mealybugs

Five parasitoid species: *Allotropa musae* Buhl, *Leptomastix dactylopii* Howard, *Coccidoxenoides perminutus* Girault [= *C. peregrinus* (Timberlake)], *Leptomastidea abnormis* (Girault) and *Anagyrus pseudococci* (Girault) were tested on caged single plants infested with the citrus mealybug, *Planococcus citri* (Risso). Subsequently, three of these species (*A. musae*, *C. perminutus* and *L. dactylopii)* were evaluated in a crop experiment. The parasitoids suppressed mealybug colonies when released near the hotspot at high rates (150 per plant per week, during four weeks). Active dispersal, however, was poor.

Phytoseiids were released in far higher numbers. In five species tested (*E. ovalis*, *A. swirskii*, *I. degenerans*, *N. cucumeris* and *A. aurescens*), none could prevent the development of mealybug colonies.

CURRENT IMPLEMENTATION OF IPM ON ROSES IN COMMERCIAL GREENHOUSES (TABLE 1)

Management of spider mites

The introduction of the predatory mite *P. persimilis* against spider mites is becoming common practice. Pest-in-first is not popular because growers fear the proliferation of introduced spider mites in their crop. *P. persimilis* is then introduced locally in resident hotspots of spider mites or in the whole crop by higher infestation. Growers sometimes observe the predator to turn up spontaneously in new hotspots of spider mites. Maybe it managed to reach a new colony just before the old one became extinct. Passive dispersal via

Table 1 Principal control agents and chemicals used in greenhouse rose production within Integrated Pest Management systems in the Netherlands in 2008.

Pests and diseases	Biological agents	Chemicals
Thrips	*Amblyseius swirskii*	lufenuron
	Amblyseius cucumeris	spinosad
		abamectine
Spider mites	*Phytoseiulus persimilis*	bifenazate
	Amblyseius	hexythiazox
	californicus	fenbutatin oxide
	Amblyseius andersoni	clofentezine
		abamectine
Whiteflies	*A. swirskii*	pyriproxifen
		buprofezin
		imidacloprid (drench)
		acetamiprid
		thiamethoxam
Aphids		flonicamid
		pymetrozine
		imidacloprid (drench)
		pirimicarb
Caterpillars	*Bacillus thuringiensis*	teflubenzuron
		methoxyfenozide
		indoxacarb
Scales and mealybugs		imidacloprid (hot spots)
		deltamethrin (hot spots)

people (workers, visitors) may contribute to this phenomenon. So the interaction between this predator and spider mites, though unstable locally, may become semi-persistent on a larger (crop) scale.

Other predators can provide supplementary (stabilizing) effects:

- *Neoseiulus californicus* has been released for this purpose since the late 1990's. It has been used on a wider scale since 2007, after the development of a more efficient mass rearing method (Replacing its natural prey by a substitute host.) Evaluating the efficacy of these releases is difficult, as it often occurs in low density and cannot be told apart from several other phytoseiids in the field.
- Larvae of the cecidomyiid midge *Feltiella acarisuga* (Vallot) often occur spontaneously.
- *Neoseiulus cucumeris*, though introduced against thrips, can provide some effect/control of spider mites.
- *Amblyseius swirskii* is commercially available since 2005 and applied on a variety of crops. Being a predator of spider mites, thrips and whitefly, its significance will increase.
- *Amblyseius andersoni* is available since 2007. Because of its morphological resemblance to other phytoseiids, in particular *A. swirskii*, it is difficult to evaluate in the field.

Dutch rose growers have at their disposal of a variety of acaricides with which to intervene. Active ingredients include: hexythiazox, clofentezine, fenbutatin oxyde, milbemectine (since 2002), bifenazate (since 2003), spiromesifen (since 2004) and acequinocyl (since 2007). Applications of insecticides against thrips, however, often disrupt the predators/prey system.

Management of thrips

For controlling thrips, rose growers used to carry out inundative releases of *N. cucumeris* every 4 to 8 weeks, for no better reason than that this species was available and relatively inexpensive. It is expected to be replaced by *A. swirskii* in the years to come. Some growers using IPM are experimenting with combinations of both species. The choice is made depending on the available budget, seasonal abundance of pests, recommendation of their advisor, opinions of other growers and, most of all, experiences in previous years. The predators are introduced either directly on the leaves or in sachets (open rearing units). Time-saving introduction methods have been developed: the Mite Applicator (for strewing) of Certis Europe (Maarssen, The Netherlands), the Airobug® (for blowing) of Koppert (Berkel en Rodenrijs, The Netherlands) and the Bugline (sachets on a long rope, developed for chrysanthemum) of Syngenta Bioline (Essex, England).

Additionally, some growers use the soil-dwelling mites *Hypoaspis miles* Berlese or *Hypoaspis aculeifer* Canestrini for controlling the thrips (pre)pupae in the soil. A few growers are experimenting with foliar applications of the nematode *Steinernema feltiae* Filipjev. This antagonist is considered expensive and its efficacy against thrips is doubtful.

Summer outbreaks of thrips are suppressed by spraying abamectin, methomyl, methiocarb, fipronil, acephate and/or carbofuran, which usually means a break in the biological program. Today most of these compounds are no longer registered (expiry of registration of acephate in January 2003, carbofuran in December 2007) or will soon disappear (fipronil: expiry of registration in June 2009, methomyl: March 2009). New registrations of insecticides compatible with IPM are spinosad (in September 2002) and lufenuron (in July 2006).

Management of whitefly

Since 2000, rose growers are faced with increasing whitefly problems due to the declining use of broad spectrum insecticides. The whitefly parasitoid *E. formosa* was found to perform fairly well in experimental rose greenhouses, but is not very popular among rose growers. The intensive burning of sulphur against powdery mildew (1 evaporator per 50-100 m^2, 4-8 hours every night) and the spraying of neonicotinoids against whiteflies are lethal for the parasitoid. According to our experiments, the wasp deserves a better reputation by growers than it actually has (Pijnakker *et al.* 2007). Spraying selective insecticides and fungicides would enhance the possibilities of releasing *E. formosa*. Drench applications of imidacloprid and sprays of flonicamid, pyriproxyfen, buprofezine or neonicotinoids are typically carried out as soon as whitefly pupae are observed.

Researchers try to persuade rose growers to reconsider biocontrol of whiteflies by combining *A. swirskii* as a predator of eggs and crawlers with *E. formosa* as both a parasitoid and a predator of the larger nymphs. The grower should then be prepared to give up the convenience of sulphur evaporators for powdery mildew and switch over to synthetic fungicides.

Management of aphids

Against aphids, a wide range of natural enemies are available. Rose growers, however, are reluctant to use them since their tolerance to aphids is extremely low. Insecticides such as pymetrozine or flonicamid are typically sprayed as soon as aphids are sighted. Drench-applications of imidacloprid are common, while other neonicotinoids (thiacloprid, thiamethoxam, acetamiprid) are sprayed in hotspots.

Management of caterpillars

Bacillus thuringiensis Berliner is sometimes used against caterpillars of the noctuid family, but more often growers turn to methoxyfenozide, indoxacarb and teflubenzuron. These chemicals are well compatible with IPM. So the incentive to find a biological alternative is not very strong.

Management of mealybugs and scales

Mealybugs and scales form an increasing problem since pirimifos-methyl, acephate and carbofuran lost their registration. Neonicotinoids are generally sprayed on hotspots. Occasionally introduction of parasitoids or coccinellids have been undertaken but growers consider the price too high compared to the limited efficacy.

OUTLOOK

We expect that the vast majority of rose growers will adopt biological control of spider mites in the near future.

Apart from the highly specialized predator *P. persimilis*, rose growers will increasingly introduce generalist phytoseiids for stabilizing spider mite populations and for controlling thrips and minor pests.

Using natural enemies like parasitoids (against whiteflies and mealybugs) and cecidomyiids (against spider mites or aphids) is impracticable as long as growers continue to burn mineral sulphur for controlling powdery mildew. Sulphur has a disastrous effect on natural enemies.

Biological control of aphids and caterpillars is not high on the priority list of rose growers.

With IPM expanding, previously minor pests are a growing concern. Examples in The Netherlands include mealybugs, scales, tarsonemid mites, fruit tree red spider mite, citrus red mite and *Echinothrips americanus* Morgan.

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