Biological Control 54 (2010) 119–125

Contents lists available at ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Maintenance of predatory phytoseiid mites for preventive control of strawberry tarsonemid mite *Phytonemus pallidus* in strawberry plant propagation

T. Tuovinen *, I. Lindqvist

MTT Agrifood Research Finland, Plant Production Research, FI-31600 Jokioinen, Finland

ARTICLE INFO

Article history:
Received 10 December 2009
Accepted 14 April 2010
Available online 22 April 2010

Keywords:
Anthoseius rhenanus
Euseius finlandicus
Neoseiulus barkeri
Neoseiulus cucumeris
Biological control
Organic production

ABSTRACT

Effective means for the control of the strawberry tarsonemid mite, *Phytonemus pallidus*, are needed for organic strawberry plant production. To study the effect of predatory mites as a preventive control tool of *P. pallidus*, four species of predatory mites were released on mite-free strawberry plants in a greenhouse experiment. Phytoseiid mites were fed by scattering cattail pollen on leaves until the artificial infestation of the strawberry tarsonemid mite took place 6 weeks later. Population dynamics of predatory and phytophagous mites and thrips were monitored every second week by sampling leaves, runners and whole plants. The predatory mite species *Anthoseius rhenanus*, *Euseius finlandicus* and *Neoseiulus cucumeris* successfully reproduced and remained on plants when fed with pollen, whereas *Neoseiulus barkeri* failed to reproduce before the introduction of *P. pallidus*. After the artificial infestation of *P. pallidus* and the termination of pollen feeding, *A. rhenanus*, *N. cucumeris* and *N. barkeri* were able to control the build-up of tarsonemid mite populations for a period of 3 months. *A. rhenanus* and *N. cucumeris* were found to be the most promising preventive predators against *P. pallidus*. At the end of the study *N. cucumeris* and *N. barkeri* replaced *E. finlandicus* and *A. rhenanus*, and were able to form mixed populations when prey mites were richly available. However, the phytoseiid mite species used in this study could not prevent the development of the natural infestation of the two-spotted spider mite, *Tetranychus urticae*, after the initial study was terminated.

1. Introduction

The strawberry tarsonemid mite (STM) *Phytonemus pallidus* (Banks) (Acari: Tarsonemidae), is the most economically important phytophagous mite in strawberry crops particularly in multi-year strawberry production systems typical in northern Europe (Stenseth and Nordby, 1976; Tuovinen, 2000; Hellqvist, 2002). Chemical control is difficult to achieve as the most effective acaricide against tarsonemid mites, endosulfan, has been banned in European countries and the alternative acaricides available have a reduced efficacy (Fried and Schell, 2000; Labanowska, 2006a,b). The other common mite pest, the two-spotted spider mite (TSSM) *Tetranychus urticae* Koch (Acari: Tetranychidae), has been less harmful in open fields in Finland except in warm and dry seasons. The increasing practise to cover overwintering strawberry crops in autumn until the beginning of flowering in spring has increased the potential threat of both mite species even in the northernmost Finland, and in tunnel and greenhouse cultivations this threat is even greater (Tuovinen, unpublished).

The spread of STM into field crops occurs mainly through the planting of infested stock plants therefore it is critically important to prevent any initial infestation of plant propagation greenhouses. In conventional plant production, the pesticides Mesurol 500 SC (methiocarb) and Vertimec 018 EC (abamectin) are available for STM control as spring or autumn treatments in Finland (Anon., 2009a). According to the Finnish rules of organic farming, producers must obtain organically grown plants if such plant materials are available from registered organic nurseries (Anon., 2009b). As there are no effective chemical control measures available in organic strawberry plant production to control STM, there is the risk of infestation in plant nurseries. Even when certified pest free mother plants are used as initial plant materials, the hygienic control measures are always not watertight and an infestation may occur. The hot water treatment of runner cuttings to control STM before forcing is possible (Hellqvist, 2002), but saleable potted plants are difficult to treat by hot water or heated air to kill STM without injuring the plants (Fitzgerald et al., 2005).

Predatory phytoseiid mites (Acari: Phytoseiidae) are an effective tool for the biological control of mites in strawberry (Croft et al., 1998; Tuovinen, 2000; Easterbrook et al., 2001; Fitzgerald and Easterbrook, 2003). Generalist phytoseiid species can utilise, in addition to animal prey, alternative food sources such as pollen (Schausberger, 1992; Kostiainen, 1996; Abdallah et al., 2001). The concept of establishing and maintaining predatory phytoseiid mites with pollen on crops before prey animals are available has

* Corresponding author. Fax: +358 3 41882584.
E-mail address: tuomo.tuovinen@mtt.fi (T. Tuovinen).

1049-9644/$ - see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.biocontrol.2010.04.006

previously been tested and found successful in cucumber (Nomikou et al., 2002). Several widespread phytoseiid species have been observed to consume tarsonemid mites and hence to be potential biocontrol agents of STM, e.g. *Amblyseius andersoni* (Croft et al., 1998), *Amblyseius reductus* Wainstein (Tokunova and Malov, 1988; Radetskii and Polyakova, 1991), *Neoseiulus aurescens* Athias-Henriot (Fitzgerald and Easterbrook, 2003), *Anthoseius rhenanus* (Oudemans) (Tuovinen, 1995), *Neoseiulus barkeri* Hughes (Bonde, 1989; Fan and Petitt, 1994), *Neoseiulus californicus* McGregor (Castagnoli and Falchini, 1993; Fitzgerald et al., 2005), *Neoseiulus cucumeris* (Oudemans) (Croft et al., 1998; Tuovinen, 2000), *Neoseiulus fallacis* (Garman) (Croft et al., 1998), *Typhlodromips* (=*Amblyseius*) *swirskii* (Athias-Henriot) (Hernandez-Suarez et al., 2006), *Typhlodromus pyri* Scheuten (Croft et al., 1998). As some of the afore mentioned species have been reared in laboratory solely on a pollen diet, we hypothesised that these predatory mites would stay on the host plants and patrol for prey mites i.e. protect and guard the plants from accidentally invading phytophagous mites. To test this hypothesis and to gain more information of the population dynamics of selected phytoseiid species in conditions where animal food is scarce, we conducted an experiment in greenhouse conditions with four phytoseiid species, *A. rhenanus*, *Euseius finlandicus* (Oudemans), *N. cucumeris*, and *N. barkeri*. The first two species are indigenous to Finland whereas the two latter species do not occur in natural habitats in Finland. The aim of the study is to search for realistic biological control strategies against STM for plant propagation in pesticide free nurseries.

2. Materials and methods

2.1. Plants

Strawberry plants cv. 'Bounty', originally from the Laukaa Elit Plant Unit of MTT Agrifood Research Finland were propagated at a certified nursery. In March 2003, plants ($n = 120$) were planted in 24 fertilised peat bags in a 36 m^2 experimental greenhouse unit. A total of 24 cultivation channels (1 m × 33 cm) hanging from the ceiling, each large enough for one peat bag, were placed across the greenhouse unit and kept separate from each other. Automatic drip irrigation was arranged to supply water and fertilizer to the five strawberry plants planted in each bag. The plants developed only a few flower stalks and berries which were not removed – in contrast to normal plant propagation practice – to avoid the removal of any mites with them. To prevent mites spreading out of or into the channels, the hangers and irrigation hoses were covered with insect glue (Tangle-foot®). In addition, pieces of insect net were installed at the ends of the channels to hinder the growing runners to enter from one channel to another. Temperature was maintained at 22/18 °C (day/night), but a momentary maximum of over 30 °C was reached for a few days in June–August. Relative humidity was approximately 60% and varied between 35% and 95%. A photoperiod of 16/8 (L/D) was maintained by artificial lights until the natural day length exceeded 16 h in May.

2.2. Mite materials

The *P. pallidus* stock was originally sourced from an unsprayed strawberry field in Tammela, Finland (60°52′N, 23°57′E). Mites were collected one by one and then transferred to the rearing laboratory in 2002. The stock colony was maintained on strawberry plants (cv. 'Jonsok') in standard greenhouse conditions (temperature 18–22 °C, 16/8 L/D). *T. urticae* infested all plants towards the end of the experiment from the neighbouring greenhouse units.

The colony of *A. rhenanus* was also sourced from leaves collected in previous year from a strawberry field at Tammela. The colony of *E. finlandicus* originated from a mixture of mites collected in 2000 from leaves of apple (*Malus domestica*) and linden (*Tilia x cordata*) at Jokioinen. The colony of *N. barkeri* was earlier found in experimental greenhouse cultures at MTT in 2001. Commercially available *N. cucumeris* were obtained from Koppert B.V., the Netherlands. The rearing of the mites, except *N. cucumeris*, was carried out on the detached bean leaves (*Phaseolus vulgaris* L.) on moist cotton wool contained in one litre plastic containers. Mites were maintained on a diet of cattail (*Typha latifolia* L.) pollen collected in the previous summer and stored in the freezer. The rearing room temperature was kept at 25 °C, moisture at 60% RH, and continuously illuminated. The rearing followed, in principal, the method of Kostiainen and Hoy (1994).

2.3. Treatments

The treatments were as follows: (1) Untreated control without mites, (2) introduction of only *P. pallidus*, (3) introduction of *N. cucumeris* and after *P. pallidus*, (4) introduction of *E. finlandicus* and after *P. pallidus*, (5) introduction of *A. rhenanus* and after *P. pallidus*, and (6) introduction of *N. barkeri* and after *P. pallidus* (Table 1). Each treatment included four replicates of five plants in randomized plots.

The first release of predatory mites, 1 week after planting, consisted of four female and one male of each species to every plant in treatments 3–6. The young plants did not yet touch each other when the first release of predatory mites took place (18th March). The mites were collected under a binocular from the rearing arena by a fine artist's paint brush into Eppendorf tubes. The tubes were placed into the crown of the plants so that the mites would enter directly to the plant. Cattail pollen, collected in the previous summer and kept in a freezer, was offered as food by scattering a small amount to leaves of each plant three times a week. The feeding with pollen was continued 7 weeks until the introduction of STM took place (treatments 3–6). On 23rd April, two female and one male STM were introduced to the plants of the treatment 2 using the same release techniques as for phytoseiid mites. Two weeks later (6th May) the same number of STM was released to the plants in the phytoseiid treatments 3–6. The release of STM in treatment 2 was carried out 2 weeks earlier than in the phytoseiid treatments 3–6 to ensure that the starting STM population was successful and allow for the prediction of population growth in the phytoseiid treatments if predation was unsuccessful. The feeding on pollen

Table 1
Treatments, dates of introductions and number of release per plant of *Phytonemus pallidus* and predatory mites.

Treatment	Predator release I 4 females + 1 male	STM release 2 females + 1 male	Predator release II 5 females
1. Untreated	No release	No release	No release
2. *P. pallidus* (STM)	No release	23rd April	No release
3. *N. cucumeris* + STM	18th March	6th May	1st July
4. *E. finlandicus* + STM	18th March	6th May	1st July
5. *A. rhenanus* + STM	18th March	6th May	1st July
6. *N. barkeri* + STM	18th March	6th May	1st July