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Control of the strawberry mite, *Phytonemus pallidus* (Banks) in strawberry plantations by alternative acaricides

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ABSTRACT

Due to the withdrawal from the plant protection industry of several main insecticides (e.g. endosulfan, amitraz and propargite) commonly used to control the strawberry mite (*Phytonemus pallidus* spp. *fragariae*), there is a constant need to search for new control measures against this pest.

The efficacy of spirotetramat (Movento 150 OD at rates of 0.5 and 0.7 and Movento 100 SC at rates of 0.75 and 1.0 l ha^{-1}), abamectin (Vertimec 018 EC, 1.0 l ha^{-1}) and abamectin (1.0 l ha^{-1}) + the adjuvant Slippa (0.2 l ha^{-1}) for control of strawberry mite was evaluated in the current study. Pyridaben (Sanmite 20 WP, 2.25 kg ha^{-1}) was used as a reference product. All of the products were used twice at weekly intervals, after fruit harvest, when the population of *P. pallidus* exceeded the risk threshold. All products significantly reduced *P. pallidus* populations in strawberry plantations compared to control plots. The results obtained with spirotetramat were dependent on dose and formulation, and ranged from 60% to over 90% efficacy. The efficacy of abamectin for controlling the mobile forms of strawberry mite was 81–99%. This active ingredient applied in combination with the adjuvant did not display any better level of control than when applied alone (efficacy 77–95%). The results obtained with the reference product (pyridaben) were similar or slightly lower (average > 80%) than those obtained with the test products.

1. Introduction

The strawberry mite, *Phytonemus pallidus* spp. *fragariae* (Banks), also known as the strawberry cyclamen mite or the strawberry mite (Acari: Tarsonemidae), is one of the most important pests in multi-year strawberry production in many Northern European countries (Alford, 1972, 2007; Łabanowska, 2006a; Berglund et al., 2007; Tuovinen and Lindqvist, 2010; Fountain et al., 2010; Cross, 2012; Łabanowska, 2014).

The strawberry mite was first detected in Poland 80 years ago (Ruszkowski, 1935). Since then it has been considered as the most damaging strawberry plant pest (Suski, 1958; Łęska, 1964; Łabanowska, 2006a, 2014). Females overwinter in the crowns of the plant (Alford, 1972; Łabanowska, 2006b). Males constitute less than 5% of the population and reproduction is normally by parthenogenesis (Cross, 2003). The mites feed and lay eggs on the youngest leaves from early spring until the beginning of September (Alford, 2007; Łabanowska, 2006c). During May the population is low, but then increases rapidly in the summer months (after fruit harvest) to reach a peak during July–August (Easterbrook et al., 2003; Łabanowska, 2006c; Fitzgerald et al., 2008). The pest occurs in fruiting plantations, mother plantations and nursery runner stock material (Alford, 2007; Łabanowska, 2014). The mite can also migrate from plant to plant especially where the foliage touches, and from runner plants developing on the tips of stolons (Cross, 2003). There are several (3–5) overlapping generations per year (Alford, 2007; Tuovinen and Lindqvist, 2010; Fountain et al., 2010). Each generation of *P. pallidus*, from egg to adult, averages 28, 24, 12 and 9 days at 12.5, 15, 20 and 25 °C, respectively (Easterbrook et al., 2003). The mites feed inside unopened (still curled) small leaves and between tightly packed young, furled leaves (Cross, 2003). In addition to feeding on and causing damage to the leaves themselves, which itself weakens the overall health of the plant, the pest later migrates to the flower and fruit buds and then feeds on these

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also causing damage (Fountain et al., 2010; Łabanowska, 2014). It was calculated that a mite population of 38 per leaflet could reduce yield by 22% (Stenseth and Nordby, 1976). The mites inject toxic saliva into plant cells and, as a result, the leaves become wrinkled, brittle and discoloured (Alford, 2007). Severely infested plants become stunted and may even die (Łabanowska, 2006c). At the end of August and into September, young females start to search for wintering sites (Suski, 1958; Łęska, 1964). Unfortunately, it has generally been considered that all strawberry varieties are highly susceptible to strawberry tarsonemid mite (Łabanowska, 2004, 2006b; Cross, 2012).

The traditional acaricides (endosulfan, amitraz and propargite), that have been used to control this pest in the past have been withdrawn from Polish plant protection programmes, because they were not environmentally friendly (Łabanowska, 2006a). In addition, the pest is very difficult to control because of its cryptic habits, and the leaves of strawberry plants are more waxy and hairy than most other crops and are, therefore, difficult to wet (Nauen et al., 2003; Fountain et al., 2010).

For more than twenty years pyridaben (Sanmite 20 WP) which can be used only after fruit harvest has been registered for use in Polish Plant Protection Programmes (2015) and from 2013, fenpyroximate (Ortus 05 SC), which can be used once per season (i.e. before plants bloom or after fruit harvest) has been registered for use. Both products only control mobile forms of pests including the strawberry mite (Hamaguchi et al., 1995; Dekeyser, 2005; Fountain et al., 2010; Łabanowska, 2014). In addition they do not have systemic activity and their frequent application without rotation with other active ingredients may lead to induced resistance. These are some of the reasons why much research (Łabanowska, 1992, 1995, 2003, 2006a,c, 2014; Easterbrook et al., 2001; Tuovinen, 2000, 2002; Raudonis, 2005, 2006a,b; Svensson, 2008; Fountain et al., 2010) around the world is seeking to develop both new chemicals and evaluate natural enemies for controlling the strawberry mite.

Many chemicals can be effective against this species, but not all are approved for use on strawberry in all countries. However, integrated pest management (IPM) systems make use of all options to reduce pest populations with priority to non-chemical measures (IOBC, 2008). Accordingly, chemical treatments should not be done on a regular, preventive basis, but only when essential. Ideally, modern crop protection agents should be of low toxicity to beneficial predatory species in order to be used in IPM systems (Cuthbertson and Murchie, 2003; Cuthbertson, 2004; Rosell et al., 2008; Fountain et al., 2010; Cuthbertson et al., 2014).

The predatory mites *Neoseiulus cucumeris* Oudemans, *Neoseiulus fallacis* Garman, *Neoseiulus californicus* McGregor = *Amblyseius andersoni* Chant, *Typhlodromus pyri* Scheuten and *Galendromus occidentalis* Nesbitt are effective in controlling *P. pallidus* (Croft et al., 1998; Fitzgerald et al., 2007; Tuovinen and Lindqvist, 2010.). However, biological control is only effective if applied when populations are low to moderate (Croft et al., 1998); is slow acting and does not eliminate the pest on whole plants (Fitzgerald et al., 2007). This is probably because the position of *P. pallidus* in the folds of young leaves makes them inaccessible to natural enemies (Easterbrook et al., 2003; Fitzgerald et al., 2008). In addition, each female *P. pallidus* can lay up to 50 eggs so both the temperature and timing of release of predatory mites plays an important role in controlling populations (Easterbrook et al., 2003; Łabanowska, 2014). Consequently, chemical treatments are necessary to control outbreaks (Fountain et al., 2010).

Adjuvants are generally considered ecologically safe if applied at the recommended rate (Stark and Walthall, 2003). Surfactants are commonly used in agrochemical formulations as adjuvants to improve the physiochemical characteristics of the spray solution and to increase the uptake of the active ingredients into the target organism, by decreasing surface tension, contact angle and the drying time of spray droplets (Fountain et al., 2010). Adjuvants have the advantage of making it feasible to reduce the dose of a pesticide active ingredient (a.i.) (Stark and Walthall, 2003). Sometimes adjuvants can have negative effects, such as actually decreasing the killing power (antagonistic effects), increasing the formulation's ability to spread or persist in the environment (Tu and Randall, 2003).

In Poland, spring is usually quite cold and environmental conditions are not favourable for strawberry mite populations to increase. Therefore, the best time to control *P. pallidus* is after fruit harvest, when mites peak in population. However, during July and August it is possible to find more predators and natural enemies of the strawberry mite on strawberry plants, but application of pesticides after fruit harvest does not cause the accumulation of their populations due to the remains of active substances on the fruit. Considering the above concerns, in this work we evaluated the efficacy of two products: spirotetramat (lipid biosynthesis inhibition) − active ingredient of Movento 150 OD and 100 SC, and abamectin alone (chloride channel activator) − active ingredient of Vertimec 018 EC, and abamactin + the adjuvant Slippa to control *P. pallidus* on strawberry plantations in Poland after fruit harvest to identify more effective treatments for use by growers.

2. Materials and methods

2.1. Experimental plots

In the period 2009–2012 six field experiments were conducted at the Research Institute of Horticulture in Skierniewice. The private plantations were rented from growers, and localized in central Poland in Czatolin (2009), Potok Biały (2009), Bobrowa (2010) and Jamno (2010, 2011, 2012). Two to three year-old strawberry plantations with cultivars 'Darselect' and 'Honeoye' were chosen for this study. The experiments were established using a split randomized block design with four replicates each. One plot consisted of 22 m^2 of plants (4 rows × 5.5 m long, 4 plants m^{-2}, approximately 88 main plants).

2.2. Treatments

The plantations were inspected weekly to check for pests, diseases and any other problems during the whole growing season. When populations of *P. pallidus* exceeded the threshold level (2–3 mobile forms/youngest trifoliate leaf after fruit harvest) plantations were sprayed. This level of threshold was fixed a few years ago for Polish conditions (Łabanowska, 1992). In Poland, all acaricides registered for the control of *P. pallidus* only control mobile forms of the pest. For this reason, Polish plant protection programmes recommend two sprays; with a 7-day interval between them. In the summer months 7 days is enough for hatching most of the mites from eggs. The first treatment aims to control all mobile forms present on leaves, and the second application controls newly-hatched mites. The oily dispersion formulation of Spirotetramat as the insecticide Movento 150 OD at the rates 0.5 l and 0.7 l ha^{-1} was used in two experiments in the first year of investigation. In the subsequent experiments the sprayable concentrate formulation of spirotetramat was used as Movento 100 SC at the dosage 0.7, 0.75 and 1.0 l ha^{-1}. Abamectin at the rate 1.0 l ha^{-1} (Vertimec 018 EC) was applied in two experiments in 2010. In addition the adjuvant Slippa (0.2 l ha^{-1}) was used with abamectin. The treatment dates are shown in Tables 1–6. The acaricide pyridaben (Sanmite 20 WP) (causing inhibition of mitochondrial electron transport- METI) at the rate 2.25 kg ha^{-1} was used as a standard control product. All