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Research Article

Efficacy of some acaricides against the two-spotted spider mite *Tetranychus urticae* on cucumber greenhouses

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Abstract: *Tetranychus urticae* Koch is one of the most important vegetable pests in greenhouses. Due to the high reproduction rate and rapid development, *T. urticae* has a propensity for developing resistance to many classes of pesticides. One method for delaying the occurrence of pest resistance is the application of pesticides with different modes of action. The present research was performed to compare the efficacy of some acaricides against this notorious worldwide pest. The treatments were bifenazite (Kanecide 24% SC at 200 and 300 ppm), spirodiclofen + abamectin (Envidorspeed® 24% SC, 500 ppm), spiromesifen (Oberon® 24% SC, 500 ppm), bromopropylate (Neoron® 25% EC, 1500 ppm), and control (water spraying) based on randomized complete block design with three replications during the summer of 2018 in three provinces of Iran. To determine the spraying time, 30 leaves were collected randomly from each treatment, and if there were an average of 5 active mites under leaves, spraying was done. After spraying, sampling was performed in 3, 7, 14, and 21-day intervals by collecting 30 leaves from each experimental unit. In the laboratory, different developmental stages were recorded using a stereomicroscope. Results showed that the highest efficiency was on the 7 and 14 days after spraying with Envidorspeed® 500 ppm in all provinces. However, this difference wasn't significant in Tehran. In Kerman, Kanecide® 200 ppm, with an efficiency of 94.3% after 21 days, and Envidorspeed® 500 ppm, with an efficiency of 96.19% after 14 days, were the most effective chemicals. Results of these three provinces demonstrated that the efficiency of all five treatments after 14 days was more than 72%. The main purpose of this experiment is to compare the efficiency of these acaricides. All of them provided significant control in the greenhouse, and it could be recommended for population management of *T. urtica*e. However, Envirospeed® in Tehran and Qazvin, as well as Envidorspeed® and Kanecide® in Kerman, are more suggestible based on mortality.

Keywords: *Tetranychus urticae,* bifenazate, spirodiclofen, abamectin, spiromesifen**,** bromopropylate

Introduction

Greenhouse crop cultivation in Iran has expanded enormously in recent years. Concomitantly, the pest problems have increased as well (Mohammadi *et al.*, 2015). The cucumber (*Cucumis sativus* L.) is an important agricultural crop that is cultivated under greenhouse

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conditions (Olennikov and Kashchenko, 2023) and can be damaged by many pests, causing extensive yield losses (Rich *et al.*, 2013). Among the wide range of pests attacking greenhouse crops, spider mites, especially two-spotted spider mite, *Tetranychus urticae* Koch, 1836 is economically important, causing severe cucumber yield losses annually (Balkema-Boomstra *et al.*, 2003; Martínez-Ferrer *et al.*, 2006). It is a polyphagous pest that occurs on a wide range of host plants, such as cucumber in IRAN. So far, *T. urticae* has been reported to feed on over 1,100 plant species from more than 100 families (Migeon *et al.*, 2010). It imposes great expense on greenhouse growers worldwide in terms of damage and control costs (Miresmailli *et al.*, 2006).

Control of spider mites is complicated due to their ability to develop resistance to certain acaricides rapidly (Kim *et al.*, 1999; Badawy *et al.*, 2010; Van Leeuwen *et al.*, 2010). Thus, the demand for new pesticides with different modes of action has been a priority in recent years (Bruinsma *et al.*, 2021). Many modified carbazate derivatives were prepared as a new class of acaricides by Uniroyal Chemical, from which bifenazate was selected as the most promising compound for the control of phytophagous mites infesting agricultural and ornamental crops, which are considered one of the most effective acaricidal compounds for tetranychids control (Ochiai *et al.*, 2007; Liang *et al.*, 2018). Bifenazate has high toxicity and specificity both orally and topically to all life stages of *T.urticae* and *Panonychus citri*. Acute poisoning was observed with no temperature dependency. No cross-resistance was found in mites resistant to several other classes of acaricides, such as tebufenpyrad, etoxazole, fenbutatin oxide, and dicofol. In addition, bifenazate has been shown to be harmless to predaceous mites and beneficial insects (Kim and Yoo, 2002; Rhodes *et al.*, 2006), has low toxicity to mammals and aquatic life, and breaks down quickly in the environment (Ochiai *et al.*, 2007). These properties make bifenazate an excellent compound for use in integrated pest management (IPM) programs. Another selected chemical was Envidorspeed®. One of the features of this compound is a complementary superior effect of two different active substances, abamectin and spirodiclofen, with different mechanisms of action. Abamectin is a risk-reduced neuroactive insecto-acaricide (chloride channel activator). It is isolated from the fermentation of a soil bacterium *Streptomyces avermitilis*. Abamectin is an effective pesticide that is labeled for the control of many insects and mites (Hamedi *et al.*, 2011). Spirodiclofen, as another ingredient of Envirospeed, belongs to the acaricidal group of spiroyclic tetronic acid derivatives newly discovered and developed by Bayer Crop Science with excellent efficacy against all developmental stages of important mite pests such as *T. urticae*, *Panonychus ulmi*, *P. citri*, *Aculus schlechtendali*, *Phyllocoptruta oleivora*, and *Brevipalpus phoenic* (Wachendorff *et al.*, 2000). It shows no cross-resistance to currently available acaricides, including hexythiazox, clofentezine, mitochondrial electron transport inhibitors (e.g. pyridaben), abamectin, and others. Its broad spectrum of activity, excellent long-lasting efficacy, good plant compatibility in all relevant crops, and lack of cross-resistance make spirodiclofen an excellent compound for use in the most important markets for specific acaricides (Nauen, 2005). Spiromesifen is a novel insecticidal/acaricidal compound derived from spirocyclic tetronic acids and is a lipid biosynthesis inhibitor. It is recommended for the control of spider mites, white flies, and psyllids that act effectively via inhibition of acetyl-CoA-carboxylase, a lipid metabolism enzyme (Kontsedalov *et al.*, 2009). The last one is bromopropylate, which is a relatively durable contact acaricide that has strong toxicity against adult females of *T. urticae*. Moreover, it is effective in relatively high concentrations of resistant mites to phosphorus compounds (Mokhtari *et al.*, 2022). Generally, Mokhtari *et al*. (2022) revealed that bromopropylate could be a good option for *T. urticae* population management because of its strong efficacy and persistent control against this important pest. The purpose of the present research is to compare the efficacy of the pesticides mentioned above against *T. urticae* in the greenhouse in three provinces of Iran.

Materials and Methods

Pesticides

Tested pesticides were bifenazite (Kanecide® 24% SC) with two concentrations, spirodiclofen + abamectin ® (Envidorspeed 24% SC), spiromesifen (Oberon® 24% SC) and bromopropylate (Neoron® 25% EC).

Greenhouse Assay

The research was conducted based on a completely randomized design with six treatments and three replicates in three provinces of Iran consisting of Kerman, Qazvin, and Tehran in the greenhouse in 2018. Treatments were:

1. Bifenazite (Kanecide® 24% SC) at 200 ppm
2. Bifenazite (Kanecide® 24% SC) at 300 ppm
3. Spirodiclofen + abamectin (Envidorspeed® 24% SC) at 500 ppm
4. Spiromesifen (Oberon® 24% SC) at 500 ppm
4. Bromopropylate (Neoron® 25% EC) at 1500 ppm
6. Control (water spraying).

The treatments were applied in a 40- 60 m^2 cucumber greenhouse 3 months after planting Royal 189 cultivars at Kerman, Tehran, and Qazvin. Each plot was 7 m^2 with a 1 m border. Two rows beside the greenhouse walls were not included in the test. A 20-L Pumped Back Sprayer was used for the spray. For each experimental plot, 5 L of the solution was applied. To determine the spraying time, 30 leaves were collected randomly from each treatment, and if there were an average of 5 active mites under 30 percent of the observed leaves, spraying was done. After spraying, sampling was performed 3, 7, 14, and 21 days after initial spraying by collecting 30 leaves from each experimental unit. The treated cucumber leaves were transferred in plastic bags to the laboratory, and different developmental stages were recorded using a stereomicroscope.

Statistical Analysis

The percentage of reduction was estimated according to the equation of (Henderson and Tilton, 1955) as a criterion of pesticide efficiency.

The formula of Henderson and Tilton (1955):

$$Population reduction(\%) = (1 - \frac{Ta \times Cb}{Tb \times Ca}) \times 100$$

Ta = number of *T. urticae* after spray.
Tb = number of *T. urticae* before spray.
Ca = number of *T. urticae* in the control after spray.
Cb = number of *T. urticae* in the control before spray.

The above formula was used to calculate the reduction rate among the *T. urticae* population after the application of the six above-mentioned treatments. The data were subjected to analysis of variance (ANOVA), and the means were compared using Duncan's multiple range test at 0.05 level using the SAS 9.1 program.

Results

Kerman

The analysis of variance of data is shown in Table 1. The results show that there was a significant difference among treatments on the 21^{st} day after the application ($F = 0.26$, $df = 4, 8$, $P < 0.05$). In all treatments, the efficacy of treatments was equal on the 3^{rd}, 7^{th}, and 14^{th} days after pesticide application. After 21 days, the highest efficiency was observed in Keneside 0.2%, with a mean mortality of 94.30%. The mortality rates between Kanecide® at 0.2 and 0.3 were not significantly different based on the Duncan test. The lowest efficiency was in Envidorspeed® with a mean mortality of 76.13% (Table 2). As it caused a mortality of 96.19% on day 14^{th}, it can be comprehended that the efficiency of Envidorspeed® decreased after 14 days, which is contrary to Kanecide®.

Tehran

The analysis of variance of data showed that there was not a significant difference among treatments on the 3^{rd} ($F = 0.25$, $df = 4, 8$, $P = 0.85$), 7^{th} ($F = 3.16$, $df = 4, 8$, $P = 0.10$), 14^{th} ($F = 1.72$, $df= 4, 8$, $P = 0.26$) and 21^{st} ($F = 0.26$, $df = 4, 8$, $P = 0.85$) days after the application (Table 2).

Qazvin

According to the results, there was a significant difference in the efficiency of pesticides against *T. urticae* after 7 days (Table 3). Envidorspeed®, with a mean mortality of 94.28%, was the most effective pesticide after 7 days. On the contrary, Keneside 0.2 and 0.3, with mean mortality of 73.10% and 75.46%, respectively, caused less mortality after 7 days. There wasn't any significant difference between treatments on the 3rd, 14th, and 21th days after application.

Table 1 Pesticide efficiency against *Tetranychus urticae* in a cucumber greenhouse in Kerman in 2018.

Treatment	Population reduction ± SE (%)			
	3 days	7 days	14 days	21 days
Kanecide® 0.2	82.36 ± 2.87 a	96.37 ± 1.54 a	86.10 ± 4.81 a	94.30 ± 0.95 a
Kanecide® 0.3	80.32 ± 4.60 a	88.45 ± 8.53 a	89.82 ± 3.19 a	83.71 ± 2.72 ab
Oberon®	67.13 ± 4.92 a	87.58 ± 2.00 a	93.61 ± 3.89 a	86.93 ± 6.59 ab
Envidorspeed®	72.09 ± 4.46 a	94.29 ± 1.43 a	96.19 ± 1.44 a	76.13 ± 8.66 b
Neoron®	72.27 ± 5.03 a	79.29 ± 4.07 a	90.81 ± 2.91 a	78.48 ± 2.66 ab

Pesticide efficiency is based on a formula by Henderson and Tilton (1955).
Means in a column followed by different letters are significantly different (Duncan's multiple range test, $P < 0.05$).

Table 2 Pesticide efficiency against *Tetranychus urticae* in a cucumber greenhouse in Tehran in 2018.

Treatment	Population reduction ± SE (%)			
	3 days	7 days	14 days	21 days
Kanecide® 0.2	71.74 ± 7.74 a	82.03 ± 4.27 a	72.07 ± 5.89 a	73.13 ± 3.03 a
Kanecide® 0.3	72.57 ± 6.91 a	80.83 ± 1.58 a	75.82 ± 8.55 a	81.22 ± 2.82 a
Oberon®	64.9 ± 10.57 a	61.46 ± 10.23 a	86.17 ± 6.91 a	64.82 ± 3.72 a
Envidorspeed®	74.73 ± 8.87 a	86.43 ± 5.90 a	91.47 ± 1.63 a	76.47 ± 8.12 a
Neoron®	80.56 ± 3.41 a	80.34 ± 5.80 a	82.35 ± 7.63 a	74.71 ± 1.36 a

Pesticide efficiency is based on a formula by Henderson and Tilton (1955).
Means in a column followed by different letters are significantly different (Duncan's multiple range test, $P < 0.05$).

Table 3 Pesticide efficiency against *Tetranychus urticae* in a cucumber greenhouse in Qazvin in 2018.

Treatment	Population reduction ± SE (%)			
	3 days	7 days	14 days	21 days
Kanecide® 0.2	78.23 ± 5.45a	82.91 ± 8.61b	84.09 ± 3.39 a	73.10 ± 6.18 a
Kanecide® 0.3	83.85 ± 5.02a	79.83 ± 5.32b	77.38 ± 3.54 a	75.46 ± 1.59 a
Oberon®	70.79 ± 10.57 a	87.67 ± 10.23ab	74.09 ± 6.91 a	73.23 ± 3.72 a
Envidorspeed®	83.44 ± 6.92 a	94.28 ± 1.77a	82.18 ± 2.86 a	63.46 ± 6.87 a
Neoron®	70.05 ± 3.09 a	84.66 ± 4.33 ab	81.56 ± 4.56 a	73.32 ± 4.00 a

Pesticide efficiency is based on a formula by Henderson and Tilton (1955).
Means in a column followed by different letters are significantly different (Duncan's multiple range test, $P < 0.05$).

Discussion

Results obtained from toxicity assays of the tested pesticides showed that Kanecide® was the most efficient chemical against the two-spotted spider mites in Kerman after 21 days. Envidorspeed® was the most effective chemical against the two-spotted spider mites in Qazvin after 7 days. Oberon® was less effective in Tehran, which indicates that the two-spotted spider mite population in Tehran was probably more resistant to Oberon® than Kerman and Qazvin. The resistance of *T. urticae* populations against spiromesifen was reported in some countries such as Turkey, Brazil, Amman, and India (Sato *et al.*, 2016; Bachhar *et al.*, 2019; İnak *et al.*, 2022) as well.

In Neoron® and Envidorspeed® treatments, the efficiency of pesticides was increased by the time passing up to 7-14 days. After that, the efficiency was decreased. Oberon® partly complied with this trend. However, Kanecide® had relatively consistent efficiency for up to 21 days. So, this component was probably more effective as time passed. However, it will be needed for supplemental study.

Generally, Envidorspeed® and Kanecide® were the most effective components in Kerman and Qazvin, respectively. Envidorspeed® is a mixture of two acaricides abamectin and spirodiclofen. Abamectin is a low-activity neurotransmitter acaricide and is considered a chloride channel activator. It is isolated from the fermentation of the soil bacterium *S. avermitilis* (Lasota and Dybas, 1991). Abamectin is very effective against *T. urticae* adults and causes 100% mortality when exposed to the field-recommended dose of abamectin (Lagziri and El Amrani, 2009; Uddin *et al.*, 2015). On the other hand, abamectin, which is one of two ingredients of Envidorspeed® was reported as a harmful pesticide against phytoseiid mites (Graffon-Cardwell and Hoy, 1983; Zhang and Sanderson, 1990; Ibrahim and Yee, 2000; Bostanian and Akalach, 2006; Nadimi *et al.*, 2009; Hamedi *et al.*, 2011; Khodayari and Hamedi, 2021) as the most important, effective and wide spread predator of two-spotted spider mite and other predators of this pest (Strong and Brown, 1987; Bostanian and Akalach, 2006; Kim *et al.*, 2006). Another active ingredient of envidorspeed®, spirodiclofen, is safe and beneficial, has low mammalian toxicity, and has short environmental persistence (Dekeyser, 2005).

Bifenazate, as the active ingredient of Kanecide®, is a novel acaricide developed in recent years, which is a specific acaricide to spider mites primarily active against motile stages but also controls the eggs of some species, particularly *T. urticae* (Ochiai *et al.*, 2007). At present, it is used to control spider mites on a variety of crops, including fruits and ornamental plants (Van Nieuwenhuyse *et al.*, 2012). Additionally, bifenazate does not adversely affect predatory mites (Kim and Yoo, 2002). In another study, exposure to bifenazate did not reduce fecundity, longevity, or prey consumption of *Phytoseiulus persimilis* and *Neoseiulus californicus* (Kim and Seo, 2001) and bifenazate could be used as a selective acaricide in an integrated pest management program because it appeared much more toxic to *T. urticae* than to *Amblyseius womersleyi*. Additionally, authors expect that concentrations lower than the recommended field rates of this acaricide will enhance the survival rates of adult females and immatures of *A. womersleyi*. For long-term spider mite biological control and integrated pest management, this acaricide at reduced concentrations might be used to adjust the prey/predator ratio by reducing two-spotted spider mite numbers (thus maintaining control) while allowing predators to survive by feeding on surviving two-spotted spider mites (Kim and Seo, 2001). As in the current study, Kanecide® was effective against *T. urticae* in the lowest recommended concentration for up to 24 days. It can be used for the goal mentioned above at a lower dose.

Furthermore, it has rapid knockdown and no cross-resistance with other acaricides. These properties mentioned above make bifenazate an ideal pesticide for spider mite control (Ochiai *et al.*, 2007). Two compounds, spirodiclofen and Bifenazate, are active ingredients of Envidorspeed® and Kanecide®, respectively, that are in particular safe to beneficial, have low mammalian toxicity, and have short environmental persistence (Dekeyser, 2005). In conclusion, among Kanecide® and Envidorspeed®, which were the most effective tested chemicals against the two-spotted spider mites in this study, Kanecide®, which has fewer side effects on natural enemies, mammals and aquatic organisms, according to reports, is more proper to use in this pest management.

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کارایی چند کنه‌کش روی کنه تارتن دولکه‌ای *Tetranychus urticae* در گلخانه‌های خیار

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چکیده: کنه تارتن دو لکه‌ای *Tetranychus urticae* koch یکی از آفات مهم سبزیجات در گلخانه‌ها است. با توجه به نرخ بالای تولیدمثل و رشد سریع، کنه تارتن‌دولکه‌ای تمایل به ایجاد مقاومت در برابر بسیاری از آفت‌کش‌ها را دارد. یکی از روش‌های به تأخیر انداختن وقوع مقاومت آفت، استفاده از آفت‌کش‌های مختلف با نحوه اثر متفاوت است. این پژوهش با هدف مقایسه کارایی برخی از کنه‌کش‌ها بر این آفت جهانی و مهم انجام شده‌است. در این مطالعه تیمارهای آزمایشی عبارت بودند از کنه‌ساید® (bifenazite 24% SC) در غلظت‌های ۲۰۰ و ۵۰۰ پی‌پی‌ام، انویدوراسپید® (spirodiclofen + abamectin 24% SC) ۵۰۰ پی‌پی‌ام، اوبرون® (spiromesifen® 24% SC) ۵۰۰ پی‌پی‌ام، نئورون® (bromopropylate 25% EC) ۱۵۰۰ پی‌پی‌ام و شاهد (آب). آزمایشات در سه استان ایران در قالب طرح بلوك‌هاي كامل تصادفي در ۳ تكرار در تابستان ۱۳۹۷ انجام شد. به‌منظور تعیین زمان محلول‌پاشی، ۳۰ برگ به‌طور تصادفی از هر تیمار جمع‌آوری و درصورت وجود میانگین ۵ کنه فعال در زیر هر برگ، محلول‌پاشی انجام شد. پس از محلول‌پاشی، نمونه‌برداری در فواصل ۳، ۷، ۱۴ و ۲۱ روز با جمع‌آوری ۳۰ برگ از هر واحد آزمایشی انجام شد. در آزمایشگاه مراحل مختلف رشدی با استفاده از استریومیکروسکوپ مشاهده و ثبت شد. نتایج نشان داد که بیش‌ترین راندمان در روزهای ۷ و ۱۴ روز پس از محلول‌پاشی با انویدوراسپید ۵۰۰ پی‌پی‌ام در هر سه استان بود، هرچند این تفاوت در تهران معنی‌دار نبود. در کرمان کنه‌ساید ۲۰۰ پی‌پی‌ام با کارایی ۹۴/۳ درصد پس از ۲۱ روز و انویدوراسپید ۵۰۰ پی‌پی‌ام با کارایی ۹۶/۱۹ درصد پس از ۱۴ روز مؤثرترین مواد شیمیایی بودند. نتایج این سه استان نشان داد که کارایی هر پنج تیمار پس از ۱۴ روز بیش از ۷۲ درصد بود. با توجه به این‌که هدف اصلی انجام این آزمایش مقایسه کارایی این چهار کنه‌کش بود، همه آن‌ها کنترل معنی‌داری از کنه تارتن در گلخانه داشته و می‌تواند برای مدیریت جمعیت کنه تارتن دولکه‌ای استفاده شود. با این‌حال انویدوراسپید در تهران و قزوین و انویدوراسپید و کنه‌ساید در کرمان براساس میزان مرگ‌ومیر می‌تواند بیش‌تر توصیه شوند.

واژگان کلیدی: کنه تارتن‌دولکه‌ای، بیفنازیت، اسپیرودیکلوفن، آبامکتین، اسپیرومسیفن، بروموپروپیلات