



## Influence of air temperature and humidity on *Stratiolaelaps scimitus* (Acari, Mesostigmata) locomotor activity in a laboratory experiment

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*Stratiolaelaps scimitus* (Womersley, 1956) (Acari, Mesostigmata, Laelapidae) is a predatory soil mite massively produced in laboratories in many countries of the world. The existing spheres of *S. scimitus* application vary in many parameters, especially temperature and relative humidity. In this article, we analyzed temperature and humidity appropriate for fastest spread of soil predatory mite *S. scimitus*. Mites should be released to a new environment in such a way that they would distribute in a greenhouse, garden or field as fast as they can (i.e. providing maximum migration activity of *S. scimitus*), on the one hand, and provide maximum efficient control of number of target phytophage species (i.e. providing maximum trophic activity), on the other hand. In our experiment, at 14 °C temperature, most specimens of *S. scimitus* did not leave the migratory circle for 10 seconds. In 15–19 °C range, only 14.7% of mites left the migratory circle, and their examined activity in 10 s was only 5–10 mm. In 20–24 °C range, 27.5% of mites left the migratory circle, their migratory activity increased to 15–23 mm. In 25–33 °C range, the moving activity increased even more, the mites left the migratory circle at the first opportunity that had (some even jumped off the circle to the experimental field), 95.8% of the mites left the circle in 10 s, their examined activity reached 25–60 mm in 10 seconds. Study of thermo- and hygro-preferences for various groups of invertebrates helps to better describe their ecological niche in multidimensional space of ecologic factors.

**Keywords:** exploratory activity; migration activity; thermo-preferendum; hygro-preferendum; biological method of plant protection; zoophages; litter fauna.

### Introduction

For poikilothermic organisms, temperature and humidity are important environmental factors. Those parameters determine the rates of biochemical reactions inside cells and metabolism of organism in general (Ebssa et al., 2004; Guschina & Harwood 2006; Waqas et al., 2020; Ramachandran et al., 2021). Temperature and humidity have effects on behaviour reactions: search of food, reproduction, migration (Buczek et al., 2017; Requena-García et al., 2017; Martynov et al., 2019). Spread of species in the ecosystem and density of populations of many invertebrates are determined by those parameters (Brygadyrenko, 2015a, 2015b; Aupic-Samain et al., 2021; Rawhat et al., 2021). Global climate changes make studies of ranges of temperature and humidity preferred by the species especially relevant (Avtaeva et al., 2021; Brygadyrenko et al., 2021; Makaida et al., 2021).

*Stratiolaelaps scimitus* (Womersley, 1956) (Mesostigmata, Laelapidae) is a predatory soil mite, massively produced in laboratories of Europe, Asia, Australia, North and South Americas (Jess & Schweizer, 2009; Yan et al., 2021). The method of mass breeding of laelapid mites was developed in 1990, making *S. scimitus* commercially available in many countries (Walter & Oliver, 1990; Freire & de Moraes, 2007; Barbosa & de Moraes, 2016).

In Brazil, *S. scimitus* has been recorded and is applied to all vegetable and ornamental plants where *Bradysia matogrossensis* (Lane, 1959) (Diptera, Sciaridae) lives, and is also used in cultivation of mushrooms *Agaricus bisporus* (J. E. Lange) Imbach, 1946 (Agaricales, Agaricaceae) to control larvae of *Coboldia fuscipes* (Meigen, 1830) (Diptera, Scatopsidae) and *Bradysia cellarum* Frey, 1948 (Diptera, Sciaridae) (Jess &

Schweizer, 2009; Wen et al., 2017; Duarte et al., 2020). In China, *S. scimitus* is used for the protection of Chinese leek *Allium tuberosum* Rottler Sprengle, 1825 (Asparagales, Amaryllidaceae) from *Bradysia ocellaris* (Comstock, 1882) (Yan et al., 2022). Mean daily predation of *S. scimitus* in 25 ± 1 °C and relative humidity of 75 ± 10% equaled 8.25 larvae of *B. ocellaris*, *B. affinis* (Zetterstedt, 1838) (Diptera, Sciaridae) (da Duarte et al., 2021). In America, *S. scimitus* is used not only in agriculture, but in terrariums for treatment of reptiles *Pogona vitticeps* (Ahl, 1926) (Squamata, Agamidae) against parasitic red velvet mites Trombididae (Trombidiformes, Trombiculidae) (Schilliger et al., 2013; Mendyk 2015) and treatment of slugs *Helix pomatia* Linnaeus, 1758 (Stylommatophora, Helicidae) against white snail mite *Riccardoella limacum* (Schrank, 1776) (Trombidiformes, Ereyetidae).

*Stratiolaelaps scimitus* feeds on soil stages of most species of thrips (Berndt et al., 2004a, 2004b; Jung et al., 2019; Park et al., 2021a). Three species *Frankliniella occidentalis* (Pergande, 1895), *F. intonsa* (Trybom, 1895) and *Thrips palmi* Karny, 1925 (Thysanoptera: Thripidae) were found to be appropriate food for all active stages of *S. scimitus*, the predation level of females was 2.6–2.8 times higher than in deutonymphs. Female *S. scimitus* equally prey on imagoes of thrips and other stages of their development. Deutonymphs of *S. scimitus* prefer larvae and nymphs, and rarer prey on thrips' imagoes (Park et al., 2021b).

Entomopathogenic fungus *Beauveria bassiana* (Bals.-Criv.) Vuill. (1912) (Hypocreales, Cordycipitaceae), used in the form of granules, had no negative effect on *S. scimitus* (Sun et al., 2018). In favourable conditions, entomopathogenic fungi effectively parasitize numerous populations of phytophages, but in unfavourable conditions, the effectiveness of entomopathogenic fungi is low (Islam et al., 2021). In Germany, fungi-

cides used in vineyards in standard schemes of plant protection had no effects on activity of entomopathogenic fungi in soil (Uzman et al., 2018). Entomopathogenic fungus *B. bassiana* does not parasitize *S. scimitus*, but infects *F. occidentalis*; this allows their mutual use in integrated schemes of plant protection (Sun et al., 2018).

The studies revealed predatory potential of *S. scimitus* against a harmful phytophage – western corn rootworm *Diabrotica virgifera* LeConte, 1868 (Coleoptera, Chrysomelidae). This mite prefers first-age larvae of *D. virgifera* rather than eggs (Pasquier et al., 2021). Diet of female *D. virgifera* does not affect the further dietary preferences of *S. scimitus*. The existing spheres of application of *S. scimitus* currently vary in parameters, especially temperature and relative humidity. Therefore, the objective of our study was locomotor activity of *S. scimitus* in gradients of temperature and humidity. The obtained data would be useful for integrated schemes of protection to determine optimum periods of introduction of this zoophage and creating optimum conditions for its search activity.

## Materials and methods

**Colony of predatory mites.** A group of *S. scimitus* mites comprising 25,000 individuals was received from Bioprotection laboratory (Ukraine) in a rounded plastic 1 L tube (9 cm in diameter, 16 cm high). The *Stratiolaelaps scimitus* were in a mixture of peat and vermiculite, with insignificant amount of mites of *Tyrophagus putrescentiae* (Schrank, 1781) (Sarcoptiformes: Acaridae) for food.

**Laboratory stand.** To determine locomotor activity of mites, we used a polypropylene (PP) cylinder (44 cm in diameter, 24 cm in height) (Titov & Brygadyrenko, 2021; Nehrii & Brygadyrenko, 2022). On the bed of the cylinder, we put the experimental field, where grey circles were drawn around the center every 10 mm (Fig. 1). Those regular circles formed a coordinate system for fast visual measurements of locomotor activity of mites. The cylinder was covered by transparent sheet of 5 mm-thick polymethyl methacrylate (PMMA). On top of it, we put a Samsung S20 FE Vietnam 2020 video-recording device, equipped with optical stabilization and autofocus (wide-angle camera with  $f/1.8$  diaphragm,  $1/1.76''$  matrix,  $1.8 \mu\text{m}$  pixels). The video was recorded in  $1,440 \times 1,440$  pixels resolution.

**Migration circle.** The main problem for the experiment was isolation of *S. scimitus* group from the substrate. As the animals enter the experimental zone, they could not be subjected to stress and mechanical disturbance in order to make migration process as natural as possible. We devised a relatively simple method of migration circle. The migration circle was made of polyesterol (PET); this material provides transparency, roughness and resilience. The thickness of the migration circle was 500

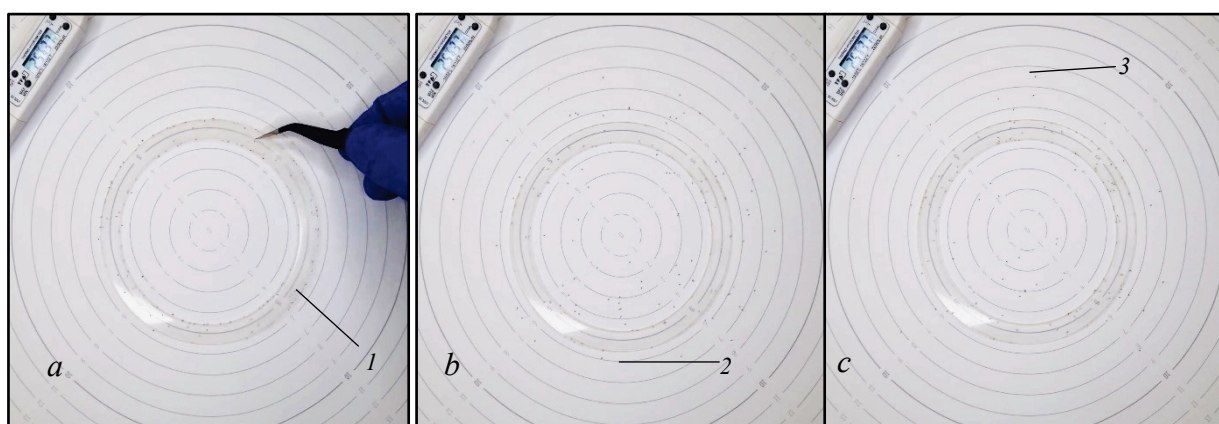
$\mu\text{m}$ , the inner diameter – 9 cm, the outer – 11 cm, mass – 1.8 g. To make mites perceive the migratory circle as a part of the substrate, it was put into a bucket with mites on the substrate.

**Preparation for the experiment.** In 24 h until the beginning of the experiment, the mites were transferred with the substrate into a 5 L bucket (width – 28 cm, depth – 18 cm, height – 15 cm), and the migration circles were put randomly on the substrate. The bucket was hermetically covered by a lid. A hole (6 cm diameter) with a small grid provided ventilation in the bucket. To prevent mites from leaving the open bucket, we used a water barrier – the bucket was put into a vessel with 1 L of water (Jung et al., 2018). The bucket with the experimental box was placed in the laboratory with constant temperature of  $26 \pm 1 \text{ }^\circ\text{C}$  and humidity of  $60 \pm 10\%$ . Thus, the objects of the study and all equipment were in the same microclimatic conditions during 24 h.

**The course of the experiment.** To collect active mites, the migratory circle – using tweezers – was put on the substrate surface into the bucket for 10–30 seconds. Then, the circle with a group of mites (30–100 specimens) was taken from the bucket and put on the experimental field. The moment of placing the migratory circle with mites on the field was considered second zero of the experiment. The video recording of the locomotor activity lasted for 60 seconds. After the experiment, the group of mites was put into another bucket with substrate to be released into the greenhouse. The temperature and relative humidity changed in the entire room. During each experiment, changes in humidity and temperature in the experimental box were recorded using a digital pocket thermo hygrometer (TFA Kat. Nr. 30.5007, Germany 2020).

**Time choice.** We determined that most *S. scimitus* returned to the migration circle after 60 seconds. They perceived the migration circle as a part of safe substrate (shelter), because, after finding no food or other attractive objects, they returned to a safe shelter. We evaluated the farthest distances the mites travelled in the temperatures of  $+15$ ,  $+20$ ,  $+25$ ,  $+30$ ,  $+35 \text{ }^\circ\text{C}$  on 20 videotapes. The vector of the mites' movements was expressed the most in the first 10 seconds. The mites were actively leaving and returning to the migration circle during 30 seconds. We decided to measure the locomotor activity of mites on the 10th and 30th seconds.

**Analysis of the results of video recording and digital data.** The work with video was performed on a computer with high definition of the monitor. *Stratiolaelaps scimitus* were constantly moving on the migration circle and the experimental field. This allowed us to easily distinguish mites from immobile particles of the substrate. In controversial moments, we watched the video a second before and second later the moment of count. To facilitate the count, the experimental field was divided into 4 zones. We determined the positions of each mite on the 10th and 30th seconds of the experiment (Fig. 1).



**Fig. 1.** Laboratory stand for the study of moving activity of *Stratiolaelaps scimitus* mites: *a* – beginning of the experiment; *b* – 10 th seconds, *c* – 30 th seconds of the experiment; 1 – migration circle, 2 – experimental field, 3 – *S. scimitus* mite

We measured how far each mite moved from the edge of the circle using the shortest way. The distance was measured in millimeters, the data were recorded in work file. Mites on the migration circle were given 0 point, mites on the experimental field inside the circle received the value with “+” sign, and mites outside the circle were given “-” sign. The data were analyzed using the standard method of variation statistics: we calcu-

lated the mean value and mean quadratic deviation, median, first and third quartiles. We developed the laboratory stand taking into account the possibility of further study of the chemotaxis of mites. The source of aroma (cotton stick, moistened with one droplet of studied substance) was placed into the center of the field on a small support, and the studied mites were placed on the migration circle.

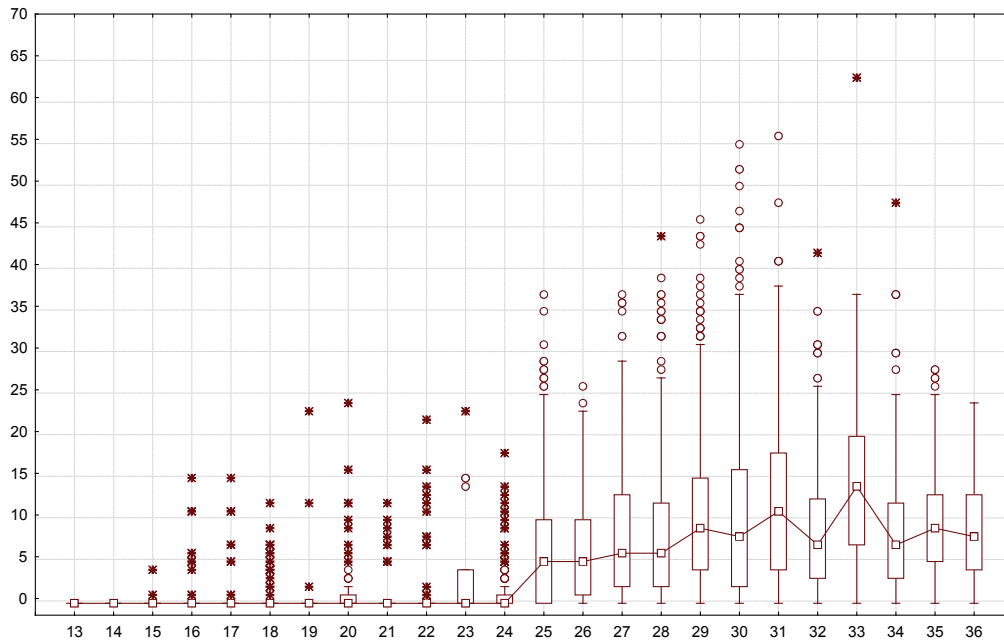
## Results

*Duration of the experiment.* In the 10th second of the experiment, most mites left the migration circle and started to move in the experimental field (Fig. 2-3). Many of them returned to the migratory circle after 15-25 seconds, having encountered no attractive food objects. A total of 4,599 mites were outside the circle at the 10th second, and only 3,334 specimens were at the 30th second (Fig. 4-5). Therefore, to determine thermo- and hygro-preferences, and also to conduct experiments with this species of mites, it was practical to determine their locomotor activity at the 10th second of the experiment.

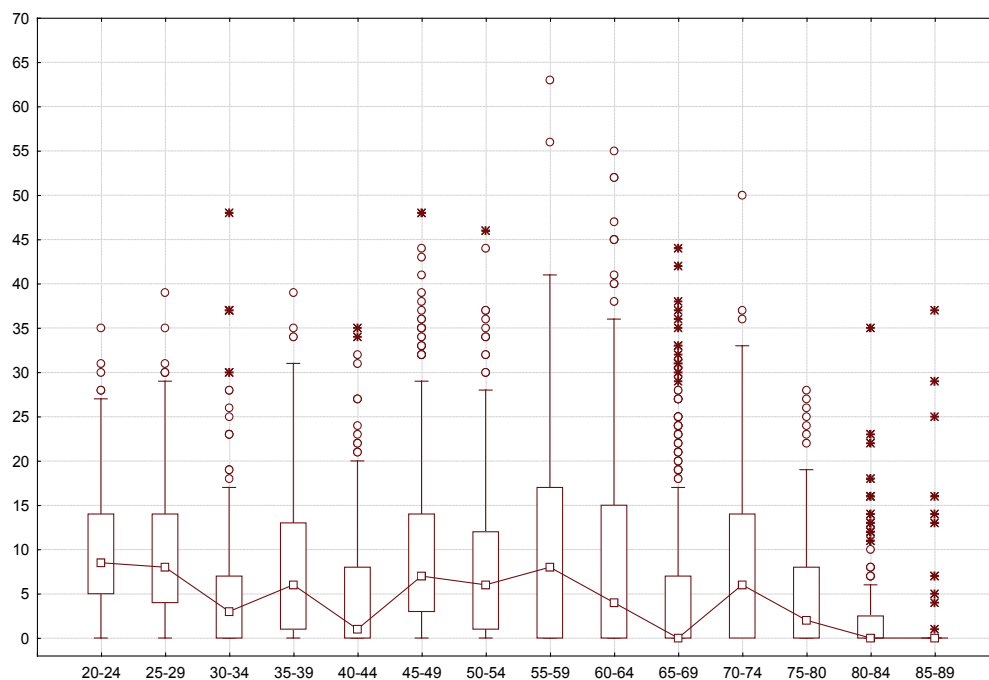
*Optimum temperature and humidity for the experiment.* The temperature in the range of 25–36 °C insignificantly affected the locomotor activity of mites (Fig. 2, 4), though in 13–24 °C, the mites moved signifi-

cantly less (Fig. 2). We observed tendency toward increase in the moving activity of mites after increasing the temperature above 25 °C. Temperature higher than 33–35 °C provided intense searching activity of the animals. The mites were probably not in their comfort zone any more, and were most likely searching for cooler conditions rather than food.

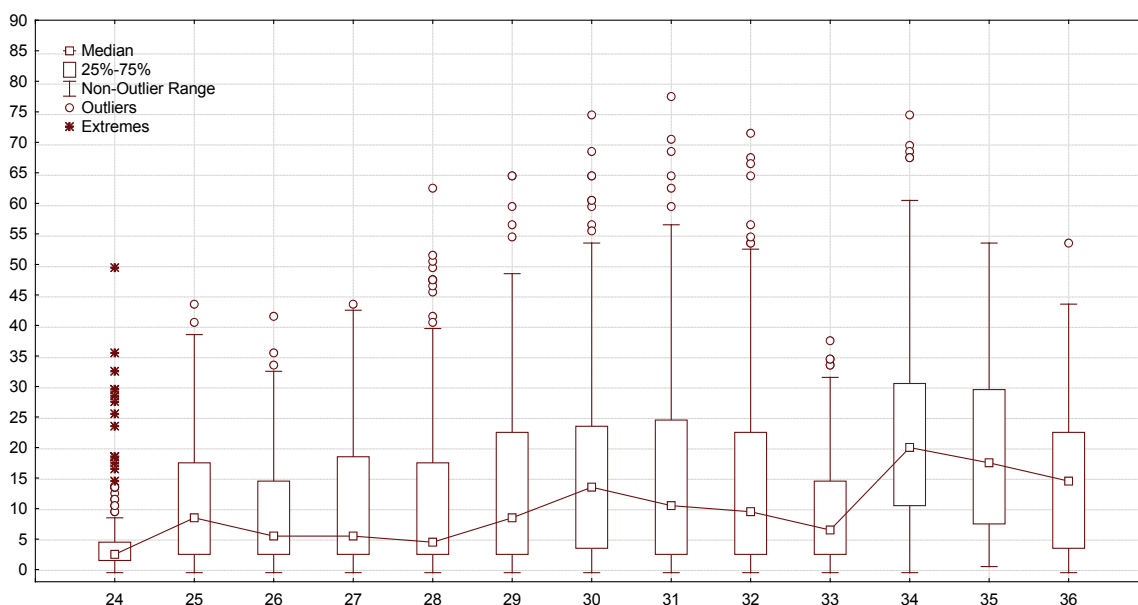
Relative humidity had little effect on the moving activity of the mites (Fig. 3, 5). In the range of 20–80% humidity, the activity of mites changed insignificantly. Interaction between temperature and humidity was most notable on the 10th second of the experiment: most active movement was seen in high temperature and humidity, while lowest activity – in low temperature and humidity (Fig. 3). On the 30th second of the experiment, in general, this tendency remained, though the dependency was less obvious, for many mites completed the first stage of the searching activity and returned back onto the circle.



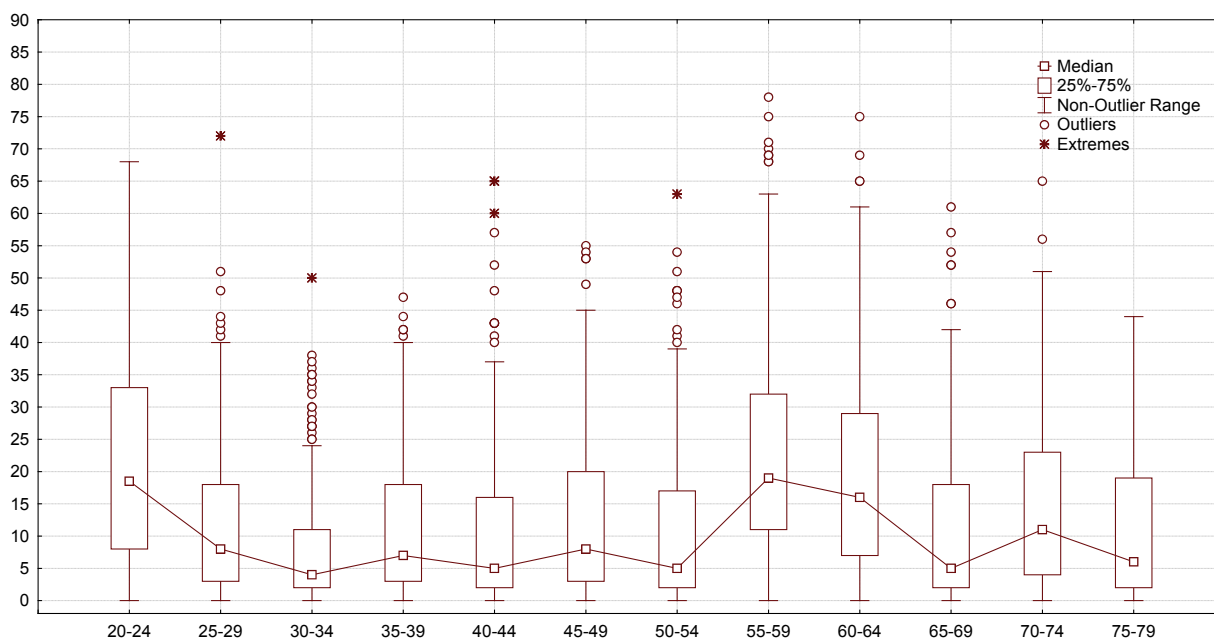
**Fig. 2.** Locomotor activity of *S. scimitus* mites at second 10 of the experiment in different temperatures: on abscissa axis – temperature (°C), on ordinate axis – distance the mite travelled in 10 s of movement on the laboratory stand (mm); N = 4599



**Fig. 3.** Locomotor activity of *S. scimitus* mites at second 10 of the experiment in different relative humidity: on abscissa axis – relative humidity (%), on ordinate axis – distance the mite travelled in 10 s of movement on the laboratory stand (mm); N = 4599



**Fig. 4.** Locomotor activity of *S. scimitus* mites at second 30 of the experiment in different temperature: on abscissa axis – temperature (°C), on ordinate axis – distance the mite travelled in 30 s of movement on the laboratory stand (mm); N = 3334



**Fig. 5.** Locomotor activity of *S. scimitus* mites at second 30 of the experiment in different humidity: on abscissa axis – relative air humidity (%), on ordinate axis – distance the mite travelled in 30 s of movement on the laboratory stand (mm); N = 3334

Since mites do not like dry air, over 85% of them left the circle to search for a more humid environment when the relative humidity was 20–29% at second 10. In 30–74% relative humidity, at second 10 of the experiment, 46–86% of the mites were moving (Table 1). The highest humidity (80–89%) decreased the number of mites that wished to leave the shelter (only 19.3–33.3% manifested searching activity).

Percentage of mites that left the circle increased after increasing the temperature from 24 to 25 °C (from 27.5% to 67.4%). In 26 °C, it increased to 75.4%, and in 27–36 °C was stably over 80% (Table 2).

At 33 °C temperature, the largest number of mites (95.9%) left the migratory circle. At this temperature, we observed the highest locomotor activity at second 10. At 34, 35, 36 °C, at second 10, the locomotor activity decreased to 25 mm and the results repeated (Fig. 2). At second 30 of the experiment, in 33 °C, most mites finished the search activity and returned to the migratory circle. The highest locomotor activity was recorded at 34 °C, with subsequent decrease as the temperature was rising (Fig. 4).

## Discussion

Growth of pesticide resistance among pests increases every year ([www.pesticideresistance.org](http://www.pesticideresistance.org)). The facts of emergence of resistance are being recorded for polyphage pests, as well as monophages. The reason why monophage pests are evolving the resistance is the intense use of pesticides in large areas of cultivation of globally popular agricultural plants (Dermauw et al., 2018). Polyphage pests are able to adapt to pesticides because of their metabolism, because due to the variability of their diet, they have to absorb toxic substances of various species of plants (Alyokhin & Chen, 2017). Resistance to pesticides is found in significant pests and in natural populations of phytophages that have not been agriculturally significant so far (Tabashnik et al., 2014). Nonetheless, there have already emerged dangerous phytophage species with universal resistance to almost all pesticides, for instance *Tetranychus urticae* Koch, 1836 (Trombidiformes, Tetranychidae), *Plutella xylostella* (Linnaeus, 1758) (Lepidoptera, Plutellidae) (Dermauw et al., 2018). The reason for the

growth of resistance is the massive use of pesticides, and therefore the scientific community is seeking for tools to limit the use of toxic pesticides, but this is impossible without the search of effective alternative tools to protect plants (Lamichhane, 2017; Lee et al., 2019).

**Table 1**  
Spread of *S. scimitus* mites in terms of their leaving the circle in gradient of relative air humidity at second 10 of the experiment (N = 4599)

Relative humidity, %	Number of mites that did not leave the shelter	Number of mites that left the shelter	Share of mites that left the shelter, %
20–24	16	108	87.1
25–29	37	285	88.5
30–34	150	241	61.6
35–39	116	405	77.7
40–44	123	196	61.4
45–49	73	462	86.4
50–54	134	491	78.6
55–59	75	185	71.2
60–64	122	172	58.5
65–69	327	284	46.5
70–74	84	191	69.5
75–80	48	61	56.0
80–84	104	52	33.3
85–89	46	11	19.3

**Table 2**  
Spread of *S. scimitus* mites in terms of their leaving the circle in air temperature gradient at second 10 of the experiment (N = 4599)

Temperature, °C	Number of mites that did not leave the shelter	Number of mites that left the shelter	Share of mites that left the shelter, %
13	5	0	0.0
14	41	0	0.0
15	47	2	4.1
16	64	11	14.7
17	94	9	8.7
18	186	20	9.7
19	62	3	4.6
20	59	20	25.3
21	39	9	18.8
22	82	16	16.3
23	16	6	27.3
24	116	44	27.5
25	184	381	67.4
26	65	199	75.4
27	84	356	80.9
28	93	418	81.8
29	54	533	90.8
30	76	357	82.4
31	19	232	92.4
32	41	203	83.2
33	4	91	95.8
34	12	99	89.2
35	8	66	89.2
36	4	69	94.5

The predatory soil mite *S. scimitus* is broadly utilized for the control of various phytophages and parasites (Schilliger et al., 2013; Mendyk, 2015; Duarte et al., 2020, 2021; Yan et al., 2021, 2022). Because of their ability to live with no food for 60 days (Wright & Chambers, 1994), this zoophage can maintain a minimum number of phytophages in the soil (Park et al., 2021b) and completely clear parasitic red velvet mites off reptiles (Trombidiformes, Trombiculidae) in terrariums (Schilliger et al., 2013; Mendyk 2015). Ali et al. (2012) determined that temperatures above 22 °C positively influence the predation of *S. scimitus*; in 24 h, this zoophage destroyed 40% of population of *Dermatomyssus gallinae* (De Geer, 1778) (Mesostigmata, Dermatomyssidae), and therefore it may be used in poultry farms for protection of laying hens (Ali et al., 2012).

In this article, we analyzed the temperature and humidity appropriate for fastest spread of soil predatory mite *S. scimitus*. Release of the mites into a new environment should provide their most effective distribution in greenhouses, gardens or fields on the one hand (i.e. provide maximum migratory activity of *S. scimitus*), and produce highest efficacy for the

control of number of target phytophage species (i.e. produce maximum trophic activity).

Temperature hugely affects the development of *S. scimitus*: its development lasts 33.7 days in 15 °C, and 9.2 days in 28 °C (Wright & Chambers, 1994). Effects of humidity and temperature on searching activity of *S. scimitus* are studied insufficiently. In our experiment, most individuals of *S. scimitus* at 14 °C did not leave the migratory circle in 10 seconds. In the range of 15–19 °C, only 14.7% of mites left the migratory circle, their searching activity in 10 s was 5–10 mm. In 20–24 °C range, 27.5% of mites left the migratory circle, and their searching activity increased to 15–23 mm. In 25–33 °C range, the locomotor activity of mites increased even more, they left the migratory circle over the first seconds of the run (some even jumped off the migratory circle to the experimental field); 95.8% of mites left the circle in 10 s, the searching activity reached 25–60 mm. The results we obtained explain the production experiment in which Messelink & van Holstein-Saj (2011) drove *S. scimitus* to plots with higher temperature of the surface by cooling the substrate during the cultivation of *Hippeastrum* Herb, 1821 (Asparagales, Amaryllidaceae).

We presume that temperature above 33 °C provokes a behaviour reaction to escape from overheating and drying. Malmström (2008) determined that *S. scimitus* die in 12 h in 30 °C, in 4 h in 32 °C, and in 1 h in 36 °C. In natural conditions, higher temperatures increase the speed of mites, but we did not observe this in our experiment. We attribute this to the fact that at the moment of the experiment, there was no temperature gradient on the experimental field, and therefore the mites could not find a vector of movement to safety. The mites made many turns, often changed the trajectory of the movement, and therefore we saw no differences in the data at second 10 (the temperature above 33 °C), but saw difference at the 30th second, when the mites gradually decreased the distance of the search activity as the temperature grew (Fig. 4).

Body length of *S. scimitus* is about 0.5 mm, and the distance the mite travels in straightforward movement is 20–40 mm, i.e., after travelling 40–80 times its body length and after finding no food, the mite changes the direction of the movement, starts zig-zagging. Trajectory of mites' movements on the surface resembles Brownian motion of gas molecules with some differences. Molecules of gas change direction under a sharp angle after colliding with another molecule. By contrast, mites can move in a curve-like trajectory even without having met other *S. scimitus* or food objects, without manifestations of any clear signals from the external environment (field for running in our experiments was each time covered by new clean sheet of polyethylene, which has not been touched with hands prior to that). A significant proportion of the mites began moving toward the initial point of the itinerary after 15 and more seconds. Mites did not run in their initial movement trajectories, and usually chose a new itinerary to return to the shelter, which likely increases the possibility to encounter food object on the return part of the trajectory.

Having small sizes, mites have significant moving abilities (Spagna & Peattie, 2012). For adhesion with the surface, mites have different elements on their legs which compensate small weight and allow mites to manifest great moving abilities in migration, fastening, attaching and even jumping for some species (Mizutani et al., 2006). For example, having 1 mm size, *Archegozetes longisetosus* Aoki, 1965 (Sarcoptiformes, Trhypochthoniidae) have traction that 1,180 times exceeds its own weight (Heethoff & Koerner, 2007). The highest relative speed in relation to body sizes was recorded for Arachnida, and one of the fastest among all animals was the relative speed of predatory Teneriffiidae mites  $10.6 \pm 0.91$  cm/s in the temperatures of 40 and 50 °C (Wu et al., 2010). For the protection from predators, mites use elements of chemical protection, sebaceous glands on the abdomen of *A. longisetosus* perform protective function. Heethoff et al. (2011) found that beetles *Stenus juno* (Paykull, 1789) (Coleoptera, Staphylinidae) consumed mites the sebaceous glands of which had been removed, and consumed no intact specimens of mites.

Dry air can dehydrate mites in a few minutes, and those running on the substrate – even faster. Therefore, the distance that *S. scimitus* travelled in our experiments drastically decreased in relative humidity below 30%. Negative effects of dry air increased with increase in temperature, and therefore mites – using all the remaining strength they had – tried to find appropriate conditions for life, and the distance they travelled in dry warm and hot air increased compared with dry cool air.

In our experiment, in humidity below 30%, mites successfully left the circle to explore the field. Their organs of senses are definitely able to trace relative humidity (Merrick & Filingeri, 2019). However, increase in humidity above 80% altered the regular behaviour of mites: in the humidity range of 80–84%, 33.3% of mites left the migration circle, and in the range of 85–89% humidity, only 19.3% of mites left the circle. Moving activity in the field also decreased in humidity above 80%. During the experiment, we noted that gravitation water poses risks: mites died 20–40 minutes after complete submersion. We may presume that mites avoid dangerous conditions and decrease their exploration activity in zones of high humidity.

On the bodies of arachnids, there are chemosensitive hairs (Foelix, 1970). When moving, mites orientate using those organs of senses, and also mechanical and thermo- and hygro-receptors. The smaller the sizes of bodies of arthropods, the fewer abilities they have to resist drying. Small size poses risk of overheating and dehydration in dry hot conditions. Given similar isolating properties of the cuticle, their ability to resist drying is directly proportionate to volume (weight) of body and inversely proportionate to its surface. Because of practically minimum possible sizes the arthropods can have, the mites we studied had the highest level of ratio of body surface area to its weight (especially in immature development stages that have not reached the sizes of adult animal equaling 0.5 mm). Therefore, thermo- and hygro-receptor should probably be one of the most important senses of perception of the environment for *S. scimitus*.

During storage of mites, before the release to the greenhouse, we observed several accumulations of *S. scimitus* (30–100 ind.) on the lower side of the bucket lid, groups of mites formed hemispheres, some mites were on tops of the others, but did not fall down. During slight knocking on the bucket, mites felt the vibration and spread across the lid in various directions, without falling down. Mite *Androlaelaps schaeferi* (Till, 1969) (Mesostigmata, Laelapidae) held to the lower surface of the glass using two sticky pads, and traces of sticky substance were left in the regions where the mites' limbs were (Peattie et al., 2011). Therefore, we think that *S. scimitus* left chemical traces of its presence on the migration circle during 24 h storage.

In our experiment, the migration circle served as a convenient substrate that did not obstruct video recording of the locomotor activity in the experimental field. The circle was put in the bucket specifically so that microparticles of the substrate from the bucket would be left on it, as well as signs of presence of the studied mites. We found that in all the runs, most *S. scimitus* left the migratory circle in the first 10 s, but after exploring the experimental field, returned to the circle during seconds 60–120 and manifested no massive exploration activity any more, even after 300 seconds. In order to confirm that mites on the circle exhausted their potential for the exploration activity, we lifted the migratory circle with mites at the height of  $10 \pm 2$  cm and after 10–20 s returned it back to the field. We observed no repeated activity: most mites remained on the circle. The behaviour pattern remained in 5 different experiments in different temperatures and humidity. Using thermo- and hygro-reception, locomotor activity is determined in general, and the movement vector is formed by chemo-reception. To search for food, mites use chemoreceptor orientating on aroma molecules. The studied mite was also found to have reaction to vibration: knocking made mites running upward. Most likely, it is adaptation for migrating to greater distances on rodents, reptiles, birds.

Chemo-receptors of mites can react to chemical signals of their species (pheromones) or other species of invertebrates and vertebrates (allomones and kairomones). In our experiment, conducted in accurately controlled conditions, without influence on mites from potentially biologically important molecules, the mites probably behaved differently than in the natural conditions. In the wild, for example, after sensing a food object, a mite can start moving toward unfavourable temperature and humidity, i.e. the stimulating effect of chemical signal may oppose the stopping reaction to unfavourable temperature and humidity. Study of the effects the chemical signals have on *S. scimitus* is a promising topic of further research.

## Conclusion

By employing this method, similar experiments may be performed on other species of small invertebrates. Study of thermo- and hygro-

preferences of various groups of invertebrates would help better describing their ecological niche in multidimensional space of ecological factors. Furthermore, determining optimum conditions of temperature and humidity is necessary for further study of reactions of the organism to chemical signals in the environment.

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