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Features description for the predatory mite *Phytoseiulus persimilis* Athias-Henriot, 1957 (Mesostigmata: fam. Phytoseiidae, subfam. Amblyseiinae)

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Abstract. The predatory mite *Phytoseiulus persimilis* A.-H. is used as a specific acariphage on vegetable and flower crops. In protected ground *P. persimilis* is the most effective predator of twospotted spider mites (*Tetranychidae*). The scopes of pesticides use in the struggle with twospotted spider mites – pests of food and flower crops – are limited by the acaricides quantity. There are resistant pest races from which it is possible to protect crops only with help of predaceous mites. The special feature of the *P. persimilis* use on protected ground is the rapid rate of population reproduction of the. The basis for the effective use of *P. persimilis* is the timely detection of twospotted spider mite foci sites and the settlement of a certain number of predaceous mites there. On the backdrop of the pesticides use, it is necessary to do surveys every 4–5 days, at a temperature of 25 °C. This mite is widely used to protect garden strawberries, especially during tunnel cultivation. Flower crops (roses can be taken as the example) are also effectively protected by phytoseiulus on shrub-shaped plants. However, flower plants under forcing treatment require more drought-resistant acariphages.

1 General characteristics of the species

The genus *Phytoseiulus Evans*, 1952 [1] is part of the family of phytoseiid mites (*Phytoseiidae*) subfamily *Amblyseiinae*. The family is included in the order Mesostigmata of the superorder of Parasitiform mites (Parasitiformes) of the Arachnid class.

The genus *Phytoseiulus* is characterized by the presence of a small dorsal shield, which occupies only part of the idiosome, on which there are 16 pairs of setae and 3 pairs of solenostomes. Some setae (D5, PL1, PL2) are missing. The channels of the peritremes are

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shortened. The ventroanal shield is strongly reduced, bears only one pair of perianal seta , the preanal pores are pointy. Females have spherical body shape.

The species *Phytoseiulus persimilis* A.-H. has an oval, slightly sculptured dorsal shield (Fig. 1(1)). For female unit length is 322, width is 224 microns. The dorsal chetome is characterized by the presence of 5 pairs of long setae (from 110 to 152 microns) and 4 pairs of elongated setae (from 42 to 69 microns). The peritremes go beyond the level of the tech AL1 setae. The ventroanal shield is reduced to the size of the anal shield (Fig. 1(2)); preanal pores are located along the edges of the shield. The female's spermateca has a long funnel, which is narrowed in the middle part, the atrium is sessile (Fig. 1(3)). Chelicerae with 3 teeth on a movable claw and 6-9 teeth on a fixed claw. There is macrochete on the leg of the IV pair (Fig. 1(8)). The male has a slightly bent spermatodactyl on a movable claw (Fig. 1(5, 6)). The ventroanal shield of the male is well developed, with pointy preanal pores (Fig. 1(7)). Valid name for the species: *Phytoseiulus persimilis* Athias-Henriot, 1957. Synonyms are *Phytoseiulus riegeli* Dosse, 1958 and *Amblyseius tardi* Lombardini, 1959.

The carnivore mite *Phytoseiulus persimilis* Athias-Henriot, 1957 was first described originating from Algeria found on greenhouse rose [2]. Its natural habitat is the Mediterranean coast, this species can have several host-plants (herbaceous, shrubby and woody), but is confined mainly to herbaceous plants. By type of diet this mite is carnivore that prefer to hunt twospotted spider mites, unable to survive and reproduce on alternative food.

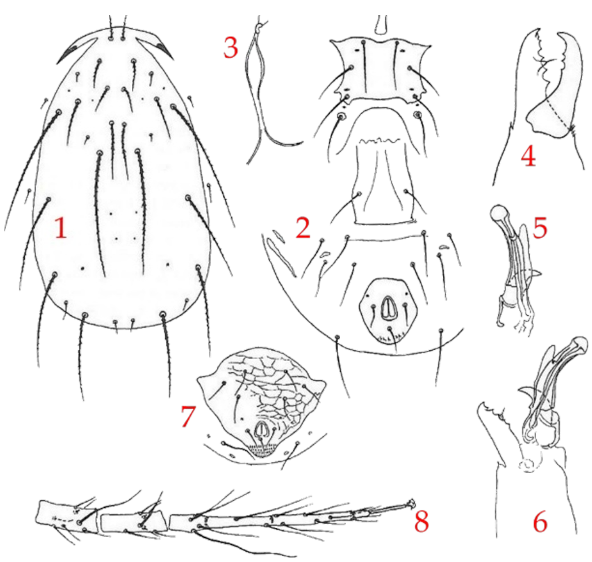

Fig. 1. Morphological features *Phytoseiulus persimilis* [3]: 1 – dorsal shield of female; 2 – fragment of the ventral side of the female's body; 3 – spermateca; 4 – female chelicerae; 5, 6 – spermatodactyl on the male's chelicerae; 7 – male ventroanal shield; 8 – macrochete on the IV leg of the female.

For this mite the multeity of victims includes various species of other herbivorous mites – *Tetranychus urticae, Tetranychus cinnabarinus, Tetranychus atlanticus, Tetranychus turkestani, Tetranychus pacificus, Panonychus citri* (fam. Twospotted spider mites Tetranychidae). In laboratory conditions, *Phytoseiulus persimilis* A.-H. developed normally when fed by the linden twospotted spider mite *Schizotetranychus tiliarum* [8]. At a relatively high temperature, after the end of the growing season, the phytoseiulus is able to continue feeding on diapausing female twospotted spider mites in their areas of accumulation for winter [4].

2 Development cycle of Phytoseiulus

The development cycle of the phytoseiulus follows simple binimphal pattern – egg, larva, nymph (proto- and deuto-), imago (female or male). However, in comparison with other species of phytoseids, this predaceous organism has significantly faster rates of preimaginal development, and at the same time shows extreme voracity. Individual development consists of several stages: from 6-legged larvae, turning into 8-legged protonymphs and further into deutonymphs, subsequently reaching the adult stage. Mating begins immediately after the last molt. The fertilized female prefers to lay eggs in colonies of twospotted spider mites, attaching these eggs to the web fibers or directly to the leaf surface.

Predator ova (eggs) differ well from spherical twospotted spider mite eggs: larger in size up to 0.25 mm long, in shape of asymmetric ellipse; colored from pale pink to yellowish-orange. The larvae are whitish-pale, length of the idiosome reaches 0.25 mm. There are a pair of long setae on the opisthosome, the locomotor apparatus is six-legged. Their development takes place with the use of the embryonic yolk. Without moving far from the exuvium, the larvae go into a state of rest, which ends with molting to the next stage. After the first molt, an 8-legged protonymph (nymph of the first age) appears, the pink body reaches about 0.3 mm. The protonymph in a 1-day period of development consumes 5 – 7 twospotted spider mite eggs. The protonymph enters a short-term rest period after sufficient feeding.

After the second molt, a deutonymph (nymph of the second age) appears. The body, brightly colored in a reddish tone, reaches length of 0.35–0.40 mm. From the previous age, the deutonymph differs in greater mobility and voracity, destroying up to 9–16 spider mite eggs in one day of development. The development cycle ends with the appearance of an adult Phytoseiulus (Fig. 2).

Fig. 2. Female of *Phytoseiulus persimilis* (Meshkov).

Adult female is drop-shaped with thin elastic integuments. The oviparous female acquires spherical shape, her body (idiosome) reaches a length of 0.5 mm. Body coloration varies from light pink to cherry depending on age and food quality [9]. There are two pairs of oral limbs and 4 pairs of walking limbs – the appendicular organs are relatively long, especially the front pair, which performs tactile and communicative functions. Often, an egg ready for laying can be seen through the chitinized integuments of the body. Adult males are slightly smaller than females (0.3 mm), but can only be reliably distinguished through the microscope.

3 Vital conditions for Phytoseiulus

Phytoseiulus is a hygrophilous species. The duration of ontogenesis is significantly affected by temperature and relative humidity. During the period of embryonic development, mites are most demanding to hygrothermal conditions. When the air humidity is below 50%, eggs die regardless of the temperature values. An increase in air humidity to a minimum of 60% ensures the development of eggs only at temperatures below 30°C, and at a humidity of 80% and more, eggs develop normally at higher temperatures (Table 1). With an increase in humidity, the development time is somewhat shortened. Thus, at 27°C, egg development lasts on average 2.4 days at 60% humidity and only 1.9 days at humidity 98 % [5, 12, 13].

Short-term (9 hours) egg content in conditions of low humidity (50%) does not have a detrimental effect on development. With a longer content (28 hours) in unfavorable humidity conditions (50%), the percentage of egg death increases sharply (up to 70%) [12].

Table 1. The effect of relative humidity and temperature on the duration of *Phytoseiulus persimilis* [5] embryonic development.

Relative air humidity, %	Duration of predator development (days) at temperature, °C						
	13	**18**	**25**	**27**	**30**	**33**	**35**
50	0	0	0	0	0	0	0
60	0	0	3.0	2.4	0	0	0
70	6.8	3.8	2.9	2.2	2.1	0	0
80	6.9	3.8	2.8	2.1	2.0	1.7	0
90	7.0	3.7	2.8	2.0	1.9	1.6	0

Larvae, nymphs and adult mites are less demanding of hydrothermal conditions. Their development is successful at air humidity from 50% and above in a relatively wide temperature range (13–33 °C).

The development of a predator from the moment of larvae hatching to the appearance of adult mites at temperature of 27°C and humidity of 50% requires 4.3 days at average and only 3.6 days at a humidity of 90%. A similar effect of humidity on the timeframes of predator development is typical for all temperature regimes (Table 2). The development of a predator is not hindered by short-term (3 – 4 hours) exposure to high temperature (40–42°C).

Table 2. The effect of relative humidity and temperature on the duration on *Phytoseiulus persimilis* [12] postembryonic development.

Relative air humidity, %	Duration of predator development (days) at temperature, °C				
	13	**18**	**23**	**27**	**30**
50	0	8.8	5.0	4.3	3.3

70	11.8	8.5	5.1	4.1	3.0
90	11.7	7.8	4.7	3.6	3.0

At a constantly low humidity of 25–30%, regardless of temperature, the phytoseiulus does not develop. The development of phytoseiulus at different temperatures occurs on average 1.5–1.9 times faster than the development of its victim, the twospotted spider mite [12]. During the development of eggs, larvae, proto- and deutonymphs, the natural mortality of the predator is observed only in the egg phase and equals 2.5% on soybeans, 5.4% on roses, 11.6% on chrysanthemums, 14.5% on carnations [9] for example.

Based on data on the duration of the development of phytoseiulus, the lower temperature threshold of its development was calculated according to the Blunk formula [14] – approximately 7°C. The sum of the effective temperatures required to complete the full cycle of predator development, depending on the conditions, ranges from 110 to 131 °C (average 120°C). According to the life tables, demographic parameters for the phytoseiulus population are calculated (Table 3).

Table 3. Demographic features of *Phytoseiulus persimilis* depending on temperature.

Parameter	Temperature, °C	
	20.3 °C [6]	25 °C [7]
Specific population increase rate (biotic potential), r_m	0.219	0.317
The maximum rate of population increase, λ	1.24	1.37
Net reproduction rate, R_0	44.4	63.2
Average generation time, T	17.3	13.1

Table 4. The voracity changes of *Phytoseiulus persimilis* on the twospotted spider mite under the air humidity variations at air temperature 27 °C [12].

Relative air humidity, %	Consumed individuals by one predator per day	
	juvenile predator	female predator
50	10.0	23.3
70	10.1	21.6
98	6.6	11.0

The voracity of the acariphage on various types of cultivated plants is relatively similar – in terms of the number of eggs consumed, it ranges from 270 to 340 pieces. The voracity and fertility of female phytoseiulus are significantly influenced by air humidity. With a decrease in air humidity, voracity increases, but the number of eggs laid decreases (Tables 4, 5). For example, at a temperature of 25°C in combination with a relative humidity of 50–70%, one female phytoseiulus destroys 21–23 spider mite individuals daily at various stages of development. At the same temperature with high humidity of 98%, only 11 prey individuals are destroyed by one female predator.

The number of eggs laid in one day at an air humidity of 30, 50, 70-98% and at a constant temperature of 25°C reached 0.8, 1.3, and 4.3 per female, respectively.

Table 5. The effect of temperature and humidity* on fertility *Phytoseiulus persimilis* females [12].

Relative air humidity, %	Duration of predator development (days) at temperature, °C				
	13	**18**	**25**	**27**	**30**
25-35	-	-	0.8	-	0.7
50	0	0.8	1.3	1.4	1.2
70	0.2	0.8	4.3	4.0	3.7
90	0.7	1.1	4.3	5.1	-
98	-	-	4.3	-	-

* *The (-) sign indicates the absence of data*

4 Laboratory population

Various populations of the predaceous mite *Phytoseiulus persimilis* are successfully cultivated in the laboratory. Currently, acariphage is bred according to methods over twospotted spider mites (family Tetranychidae) population. The common twospotted spider mite *Tetranychus urticae* is mainly used as food, less often the strawberry spider mite *Tetranychus atlanticus* is used. Twospotted spider mites are disseminated mainly on soybean plants, sometimes on beans, cucumber or forage beans.

The winter laboratory method consists in phytoseiulus breeding in special cages, at feeding the predator with diapausing female twospotted spider mites. In this method the need for green plants is abruptly reduced, which is of great importance in winter [8].

The basic method of maintaining the laboratory population of phytoseiulus is carried out on illuminated racks or in greenhouses. The necessary hygrothermal conditions are: increased humidity of 70–85% and moderate temperature in the range of 25–30°C [4].

A method of acariphage breeding on cut plants with spider mites placed in a cage of special design can also be implemented [10]. This method allows further collection of purified phytoseiulus, resettling individuals into a loose filler for subsequent use in greenhouses.

Consideration of medical and environmental safety issues arising during breeding and use of acariphage shows that predatory mite *Phytoseiulus persimilis* is safe for humans and warm-blooded animals. Allergic reactions in the maintenance personnel during its dilution and application are not recorded. The predaceous mite is safe for beneficial insect pollinators and biological control agents against harmful arthropods.

5 Scope of application

Phytoseiulus persimilis is a highly specialized oligophagus. The predator feeds on various species of twospotted spider mites, using all stages of their development as food. Acariphage can be used on vegetable and ornamental crops on protected soil, as well as on some crops in the open field conditions. The best plants for predator colonization are cucumber, tomato, eggplant, rose, strawberry and gerbera.

The basis for the effective use of phytoseiulus is the timely detection of spider mite sites foci and settlement of a certain number of predaceous mites there. The interval between surveys should not exceed 7 days. The most acceptable is the release of a phytoseiulus for each plant infected with a twospotted spider mite based on an eye estimation of the infection degree (weak, medium, high). From 10 to 60 individuals of phytoseiulus are to settle on each plant.

In neglected foci of the twospotted spider mite (untimely pest detection), the predator is released in masses to assure predator-pest ratio of at least 1:50. At each subsequent survey, it is necessary to pay attention to the reproduction of the pest and the accumulation of predators in previously identified and populated foci. If necessary (low predators accumulation and the increased spider mites reproduction) phytoseiulus is released additionally.

Optimal hygrothermal conditions for predator are the average daily temperature in the range of 26–32°C, relative humidity in the range of 70–80%. Short-term lows and highs are acceptable.

6 Conditions and terms of predatory mite culture preservation during storage

The temperature of +3°C in combination with high humidity of 90–98% is most favorable for the conservation of phytoseiulus [12]. For a long time, the phytoseiulus is stored in a state of torpor at low temperature and high relative humidity [11]. Females and males of predatory mites are better preserved, as nymphs, larvae and eggs die very quickly.

With short-term storage from 5 to 7 days, mites persist in all phases (ages) of development. In optimal conditions (temperature 3–5°C, relative humidity 90–95%), 80% of young females (average) survive for 30–35 days. An increase in the storage period to 40–45 days leads to abrupt decrease in the number of surviving mites (up to 35%). Thurthermore only single individuals can withstand long-term storage for 60 days.

At use of phytoseiulus kept in refrigeration units, the actual release rates should be calculated taking into account predators mortality caused by the shelf life. Predaceous mites taken from the refrigerator at 10°C are activated very quickly at room temperature and continue ordinary life.

The cold resistance of the phytoseiulus is relatively low, which is explained by the lack of diapause in its development cycle [12]. At temperatures below 0°C, predator survival, depending on temperature and exposure, decreases from 84.8% (at –2°C exposure for 2 days) to 0.7% (at –5°C exposure for 10 days).

7 Results of the study

Mass colonization of phytoseiulus is carried out at the foci of twospotted spider mites, usually at a rate of 20–50 females per square meter. Additional releases are carried out at intensively advancing pest foci. Depending on the ratio of the number of twospotted spider mite and its predator, positive results can be achieved at different time intervals (Table 6).

Table 6. The period (days) dependence for effective suppression of the spider mite foci on the release rate of phytoseiulus at temperature 24 °C and relative air humidity rate at 60–85% (original data).

Initial ratio	1 : 5	1 : 10	1 : 30	1 : 100	1 : 600

predator : prey	Time required to suppress twospotted spider mite population				
Minimum period	3	5	8	15	25
Maximum period	5	7	12	20	35

Obviously, with a minimum ratio of 1 : 5, the predator quickly finds its prey and quickly destroys it. The optimal ratio is 1 : 10, when within one week the phytoseiulus destroys a colony of twospotted spider mites. At this time, each female predator lays from 2 to 5 eggs, from which larvae hatch.

At a ratio of 1 : 30, the process of suppressing the pests population size is delayed up to almost 2 weeks. But during this period, young female predators appear. With a high ratio 1 : 100, the pest is destroyed within 2–3 weeks, but during this period significant damage is caused to the leaves. But also population of phytoseiulus accumulates significantly, most of the young females migrate to neighboring plants. With a very high ratio 1 : 600, colonization of phytoseiulus is impractical, since twospotted spider mites can cause unacceptable damage to cultivated crops.

8 Discussion

The *Phytoseiulus persimilis* A.-H. mite is most effective predator of twospotted spider mites. All over the Earth it is actively used in greenhouse farms on cucumber crops since the 1960s. Twospotted spider mites are polyphages and are widely distributed in nature on wild plants. There is a drift and hybridization of spider mites populations. Therefore, it is still not possible to completely eliminate the pests of twospotted spider mites even with the use of chemical formulations (at fumigation, spraying) in 60 years struggle.

The creation of resistant varieties of crops is a very long procedure (on example of the Manul company), out of nearly 50 potential hybrids tested only 2–3 samples turn out to have abilities for use by drainage and a number of other indicators [15]. Many researchers note that often the evaluated and prepared lines gain characteristics that prevent the widespread introduction of such hybrids (for example, hybrid may lose gustatory quality).

Proceeding from the complexities of chemical, selective control of twospotted spider mites (Tetranychidae) on crops, especially in greenhouses, *P. persimilis* is the most effective predator. Some cases of drug (or multidrug) resistance are registered in twospotted spider mites [16]. The risks of pesticides use against twospotted spider mites, which are pests of food, decorative, and flower crops, are found and revealed [17, 18].

The limited range of acaricides, both in terms of active substances and factors of their routine use in certain countries, cause the formation of resistant populations of harmful mites. In the Russian Federation, the multiplicity and consumption rate of pesticides application are the object of legislative control, which is generally right (as an example Flumite can be brought since the drug did not successfully go through large-scale trials).

Resistant pest populations can be limited by the use of *P. persimilis* in protected ground conditions. The basis for the effective use of *P. persimilis* is timely detection of twospotted spider mite foci and settlement of a certain number of predatory mites inside these areas (at proper calculation and accounting for fast population reproduction rate). In the open ground, mites are widely used to protect garden strawberries, especially during tunnel cultivation. Using the example of rose as a flower crop, *P. persimilis* can also be effectively used on shrub-shaped plants. Predatory mites can significantly reduce the pesticide stress on agrocenoses [19, 20]. Nonetheless, flower plants under forcing treatment require more drought-resistant acariphages.

References

1. G.O. Evans Bull. Entomol. Res. **43**, 2 (1952) DOI 10.1017/S0007485300040566
2. C. Athias-Henriot Bull. Soc. Hist. Nat. Afrique Nord. **48**, 5/6 (1957)
3. L.A. Kolodochka Bull. Zoology. **21** (Kiev, 2006)
4. G.A. Beglyarov Methodological guidelines for the mass breeding and use of the predatory mite phytoseiulus to combat twospotted spider mites in protected ground (Ministry of Agriculture of the USSR, Moscow, "Kolos", 1976)
5. G.A. Beglyarov Biological method of combating the main pests of vegetable crops in protected soil (justification and development of methods for the use of predators and parasites) (Diss. Acad. Degree Doct. Boil. Sci., Leningrad, 1987)
6. J.E. Laing Acarologia **10**, 4 (1968)
7. A. Takafuji, D.A. Res. Popul. Ecol. **17**, 2 (1976) DOI 10.1007/BF02530777
8. G.A. Beglyarov, R.A. Vasiliev, R.I. Khloptseva Methodological guidelines for the mass breeding of the predatory mite phytoseiulus and testing its effectiveness in combating twospotted spider mites in protected soil on cucumbers (Ministry of Agriculture of the USSR, Moscow, 1967)
9. N.A. Popov, O.A. Khudyakova, G.V. Pamukchi, G.A. Zhurba Methodological guidelines for the cultivation and application of phytoseiulus on roses (All-Union Scientific Research Institute of Biological Methods of Plant Protection, Chisinau, 1989)
10. G.T. Zhurba, G.V. Pamukchi, N.A. Popov, O.A. Khudyakova Plant protect. 10 (1986)
11. P.D. Koltsov, B.P. Adashkevich, V.A. Cherkasov Methodological guidelines for the organization and economic assessment of the use of phytoseiulus in closed ground in the conditions of Moldova (All-Union Scientific Research Institute Of Biological Methods Of Plant Protection, publishing house "Timpul", 1976)
12. G.A. Beglyarov, A.T. Zeszyty problemowe postepow nauk rolniczych. **129** (1972)
13. A.T. Shchekov, G.A. Beglyarov The effect of air temperature and moisture on the development of Phytoseiulus persimilis A.-H. (Thes. XIII Int. Entomol. Congr., 1968)
14. H. Blunk Zeitschrift für Wissenschaftliche Zoologie (J. Sci. Zool.) **121** (1923)
15. S.Ya. Popov, V.V. Slotin, A.V. Borisov, A.V. Kondryakov Izv. Timiryazev Agricult. Acad. **3** (2009)
16. S.A. Bubentsov, S.Ya. Popov, Achievements of science and technology of the agro-industrial complex **1**. 21-23 (2007)
17. I.N. Yakovleva, Yu.I. Meshkov, N.N. Salobukina, V.V. Mikhailova, T.A. Bereshchuk Sel'skokhozyaistvennaya biologiya (Agric.Biol.) **53**, 5 (2018) DOI 10.15389/agrobiology.2018.5.1045eng
18. I.N. Yakovleva, Y.I. Meshkov Agrochem. **3** (2016)
19. A.P. Glinushkin, I.N. Yakovleva, Y.I. Meshkov Dostizheniya nauki i tekhniki APK. **35**, 1 (2021) DOI 10.24411/0235-2451-2021-10107
20. A.P. Glinushkin, I.N. Yakovleva, Y.I. Meshkov Russ. Agricult. Sci. **3** (2019) DOI 10.31857/S2500-26272019332-34