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Aspects of use and features of the predatory mite *Neoseiulus longispinosus* (Evans, 1952) (Mesostigmata: family Phytoseiidae, subfamily. Amblyseiinae) in comparison to *N. californicus*

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Abstract. The predatory mite *Neoseiulus longispinosus* (Evans, 1952) is used as a specialized acariphage on vegetable, flower and berry crops in Asia. In protected ground of European agriculture, *N. californicus* is one of the effective predators of spider mites (Tetranychidae). The periodicity of attacks on the victim depends on the temperature. The predator prefers to hunt immature individuals of *T. urticae*, often ignoring adult female spider mites if there is a choice. *N. longispinosus* does not show preference between eggs and *T. urticae* nymphs. However, as the density of the spider mite population increases, the predatory mite switches its diet from the eggs to its larvae and nymphs. Adult females of *N. californicus* exhibit a type 2 functional response to both eggs and *T. urticae* nymphs. Pyrethroid and avermectin substances are highly toxic to predator populations, despite low acute toxicity of many other insecticides (Actara, Envidor, etc.).

1 Characteristics of the species

Neoseiulus longispinosus (Evans, 1952) is a member of the family Phytoseiidae, subfamily Amblyseiinae, order Mesostigmata, superorder Parasitiform mites (Parasitiformes), class Arachnidae. The basionym is *Typhlodromus longispinosus* Evans, 1952. The initial description is made from the holotype and two paratypes collected in a colony of the spider mite *Tetranychus bimaculatus* on Cassava Manihot utilissima in Indonesia [1].

- Historical changes in the generic (subgeneral) name:
- *Typhlodromus (Amblyseius) longispinosus* (Evans)
- *Cydnodromus longispinosus* (Evans)
- *Amblyseius longipinosus* (Evans)
- *Amblyseius (Amblyseius) longispinosus* (Evans)
- *Amblyseius (Typhlodromopsis) longispinosus* (Evans)

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- *Amblyseius (Neoseiulus) longispinosus* (Evans)

It is included in the genus Neoseiulus Hughes [2]. **At the moment, a valid name – *Neoseiulus longispinosus*** (Evans, 1952).

Neoseiulus longispinosus very similar to *Neoseiulus womersleyi* (Schicha). These two closely related species differ in dorsal setae S5. In *Neoseiulus longispinosus*, this seta is short (much shorter than S4) and smooth. In *Neoseiulus womersleyi*, this seta is long (equal in length to S4) and serrated.

The predatory mite *Neoseiulus longispinosus* is a common species in the countries of the southeastern region – China, Hawaii, Hong Kong, India, Pakistan, Sri Lanka, Indonesia, Papua New Guinea, Malaysia, Japan, South Korea, Thailand. It is also common in the Caribbean – the archipelago of Guadeloupe, Martinique, and the Dominican Republic [3]. It is found in New Zealand and Australia.

The predaceous mite *Neoseiulus longispinosus* is found on 33 plant species – from perennial (fruit trees, roses, strawberries) to annual (vegetable and ornamental crops) [4].

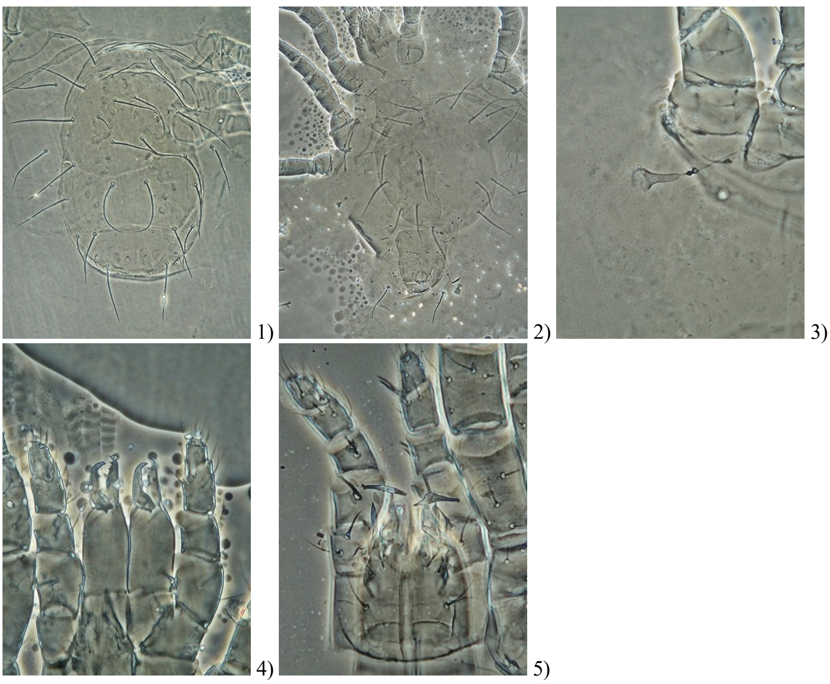

Fig. 1. Morphological features of *Neoseiulus longispinosus*: 1 – the dorsal flap of the female; 2 – the ventral side of the female's body; 3 – spermateca; 4 – female chelicerae; 5 – male chelicerae (spermatodactyl).

The development cycle of *N. longispinosus* consists of 4 phases (or stages) – egg, larva, nymph (two stages, or ages – protonymph and deutonymph), imago (female or male).

The adult female's body, depending on age and nutrition, is initially colored milky white, then successively pale pink, reddish, red, and finally dark red (Fig. 2). Body dimensions are 0.35 mm long, 0.25 mm wide; body shape is oval–ovoid but as the female matures, her body is rounded in the ventro–dorsal direction, becoming almost spherical. The dorsal shield is broadly oval (Fig. 1–1); its length is 330 microns, width is 186 microns [4]. There are 17 pairs of setae on the dorsal shield; most of the setae are long (60–80 microns), their length exceeds the distance to the bases of the setae of the subsequent rows (Fig. 1–1). One of the setae (S5) is very short, 18–25 microns. The peritremes are shortened, reaching the base of the setae j3. The length of the wind–channel shield is 123 microns, the width at the level of the ZV2 setae is 97 microns; the distance between the preanal pores is 2 times less than between the tips of the ZV3 setae (Fig. 1–2). The funnel of the spermatheca is finger–shaped, 18 (17–22) microns long, the large atrium is connected to the funnel by a distinctly isolated neck (Fig. 1–3). Movable finger cheliceris 26 microns, carries 2 widely spaced teeth; the fixed finger is 23 microns, anteriorly carries 3 teeth [5].

The male is significantly smaller than the female; the structure of the dorsal shield hetome is identical to the female, plus the S–series setae on the dorsal shield, and not on the integument. The body color is slightly straw–colored. The spermatodactyl is T–shaped

Fig. 2. Flock of female mites of *Neoseiulus longispinosus* on the threds of tetranich mites web

Eggs (ova) are pale whitish in color (Fig. 2). It has the normal shape of an asymmetric ellipse.

The larvae are pale, translucent to white in color. There are a pair of long tail setae on the opisthosome. There are only three pairs of legs. Without additional nutrition, the larva moves to the next stage (protonymph), for which, apparently, there is enough egg yolk, which the larva endogenously feeds on.

The nymphal stage (proto– and deutonymphs) consisting of two ages (phases), has four pairs of legs. The protonymph is whitish, and the deutonymph begins to acquire pinkish tinge. At this stage of preimaginal development, the predatory mite actively feeds (Table 1), and gives clear preference to the larvae of the victim, destroying up to 14 individuals of target larvae per day.

Table 1. Average daily voracity of the predatory mite *N. longispinosus* (pcs.) when feeding at various ages of the spider mite *T. urticae* (T 27±2 °C, OVV 75±10%) [6].

Prey age	**Age of predaceous organism**			
	Protonymph	Deutonymph	Male	Female
Egg (ovum)	4.9	6.0	4.3	13.1
Larva	13.6	14.5	11.3	20.0
Protonymph	5.8	12.4	11.5	17.9
Deutonymph	8.1	10.5	11.1	12.2
Female	2.4	3.1	1.6	5.1

The duration of the preimaginal development of *N. longispinosus* is significantly influenced by the ambient temperature (Table 2). At moderately low temperatures (for example, 15 ° C), the development from egg to adult lasts about 3 weeks, whereas at elevated temperatures (27–35 °C) this process takes about 4 days.

Table 2. Preimaginal development of *N. longispinosus* (days) depending on temperature.

Age of predaceous organism	Temperature, °C					
	15	**25**	**27.5**	**30**	**32.5**	**35**
Egg (ovum)	8.3	2.1	1.6	1.5	1.6	1.5
Larva	2.1	0.6	0.4	0.4	0.5	0.5
Protonymph	5.2	1.0	0.8	0.8	0.8	0.9
Deutonymph	4.6	1.2	0.9	0.8	0.7	0.8
Overall	20.2	4.9	3.7	3.6	3.5	3.7

Females of *N. longispinosus* have a short maturation period, at optimal temperatures, they lay their first egg a day after molting in imago (Table 3). The duration of the egg laying period is about 2 weeks at 25 ° C, and a little more than 1 week in the temperature range of 27÷32 ° C. At extremely high temperatures (35 °C), this period takes less than 1 week. Fertility is quite high at optimal temperatures (Table 3).

Table 3. Biological characteristics of the female *N. longispinosus* depending on temperature.

Parameter, days	Temperature, °C					
	15	**25**	**27.5**	**30**	**32.5**	**35**
Preoviposition	8.6	1.5	1.1	0.9	0.9	1.4
Oviposition	3.7	13.2	10.5	10.4	9.5	4.6
Lifespan	26.7	25.3	14.8	9.9	11.8	17.1
Fertility rate, units	7.4	47.9	49.8	56.2	53.2	32.6

According to demographic indicators (Table 4) the species *Neoseiulus longispinosus* exceeds many species of phytoseids. The biotic potential (r_m) is quite high already at 25 °C – 0.309, reaching a maximum at 30 ° C – 0.441.

Table 4. Demographic characteristics of *N. longispinosus* depending on temperature [7].

Parameter	Temperature, °C					
	15	**25**	**27.5**	**30**	**32.5**	**35**
Specific population increase rate (biotic potential), r_m	0.039	0.309	0.387	0.441	0.432	0.301
Maximum population increase rate, λ	1.040	1.363	1.472	1.555	1.540	1.351
Reproduction rate, R_0	4.4	35.3	32.3	36.6	29.9	10.4
Generation duration, T	38.1	11.5	9.0	8.2	7.9	7.8

2 Laboratory population

Mass reproduction of *Neoseiulus longispinosus* can be carried out on various species of tetranich mites (preys). Breeding technology of *Neoseiulus longispinosus*, which is almost identical to the cultivation of *Phytoseiulus persimilis*, involves the use of the common spider mite *Tetranychus urticae* as food, which is circulated on soybeans.

It is also possible to grow predaceous organisms on the spider mite *Oligonychus pratensis*. This preys are grown on cereal plants (wheat, barley, corn, millet, timothy, piggy). The spider mite *Schizotetranychus beckeri*, which lives on grasses in temperate climates, can be a promising food (prey) source. Technology of mass reproduction on a spider mite [8 - 9]. The technology of breeding a predatory mite consists of the following operations:

– plants vegetation,
– colonization plants with spider mites,
– subsequent plants colonization by predatory mites,
– assemblage of predators.

By sowing seeds of plants (for example, soybeans, beans or wheat), a "green" conveyor is created every 5–7 days, the continuity of which throughout the entire period of work is the key to successful and uninterrupted production of predators population.

For the rapid growth of plants and the successful accumulation of predatory mites where their breeding takes place, the temperature should be maintained within 25–30 ° C and relative humidity should be 75% and more.

The release of predators on plants is carried out 7–10 days after the release of the spider mite, when the pest has accumulated sufficiently. The rate of release of *Neoseiulus longispinosus* per plant equals 10 moving individuals (adult mites, nymphs). The initial ratio of the predators and spider mites should approach 1: 100 value.

The predatory mite *Neoseiulus longispinosus* is safe for humans and warm-blooded animals, and also not aggressive for beneficial insect pollinators and biological control agents versus harmful arthropods.

3 Application scopes

Neoseiulus longispinosus belongs to the group of oligophages adapted to inhabit all layers of the dense web of mites of the genus *Tetranychus*. Predation of *N. longispinosus* on spider mites has been recorded:

• *Tetranychus urticae* (common, or two–point, spider mite),
• *Tetranychus cinnabarinus* (red, or carmine, spider mite),
• *Tetranychus macfarlanei (*MacFarlane's spider mite),
• *Tetranychus kanzawai (*Kanzawa spider mite),
• *Tetranychus tumidus* (swollen spider mite),
• *Tetranychus neocaledonicus* (New Caledonian spider mite),
• * *Tetranychus truncatus* (cassava spider mite).

In addition, the predator successfully predates tetranich mites from other genera – *Panonychus citri* (citrus red mite),

• *Eotetranychus cendanai* (citrus yellow mite),
• *Oligonychus indicus* (sugar cane red mite),
• * *Oligonychus coffee (*tea red spider mite),
• *Schizotetranychus nanjingensis* (garden bamboo spider mite),
• *Aponychus corpuzae* (oriental or African bamboo spider mite).

It also feeds on tarzonemid mites, in particular *Polyphagotarsonemus* latus (the broad transparent mite).

The predatory mite *Neoseiulus longispinosus* is used in Japan to control the spider mite *Tetranychus kanzawai* in tea plantations.

An experiment to evaluate the effectiveness of the predatory mite *N. longispinosus* is carried out in a polycarbonate greenhouse (Department of Entomology, Bangalore, India), where the temperature is maintained at just below 35 °C [10]. Young tomato plants at the age of 6 weeks are artificially populated with spider mites (500 mobile individuals per plant), and after 2 weeks the predatory mite is released according to variants. The predator:prey ratio is 1:50 (option 1) and 1:100 (option 2). The predator is not released onto control plants. Predatory mites actively moved through the tomato plants as they grew.

It is found that in the first option, the predator needed 5 weeks to completely eliminate the spider mite population, while in the second option, the pest is destroyed by the end of 6 weeks after colonization of the acarifage (Fig. 3).

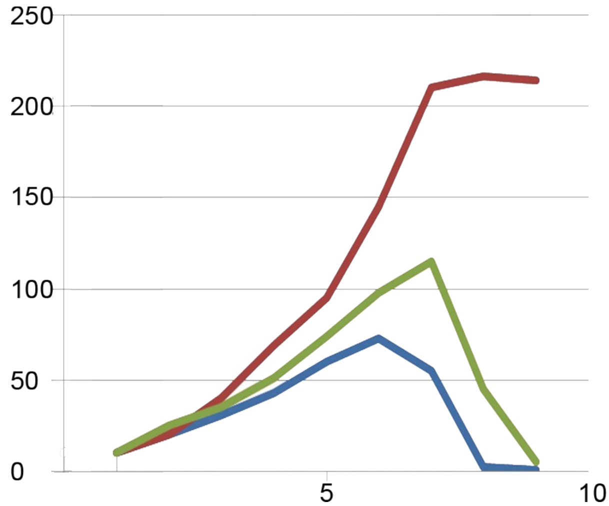

Fig. 3. Dynamics of the spider mites population (individuals per leaf share) on tomato plants after colonization by *N. longispinosus* at predator : prey ratios 1:50 (blue line), 1:100 (green line) [10].

It is important to note that living in countries with a monsoon climate, the predatory mite *Neoseiulus* (Amblyseius) *longispinosus* is most effective against spider mites at temperatures of 30–35 °C [11].

The accumulated biomaterial (predatory mite adults and nymphs) can be stored in the refrigerator for 5 – 7 days (short–term) until release at a temperature of 8 – 10 °C.

4 Results of the study

Neoseiulus longispinosus in a comparative aspect, the following data are obtained regarding the species *Neoseiulus californicus*. A more detailed comparison is presented in Table 5.

At temperature of 25 °C and RH of 56%, only 2.8% of larvae emerge from *N. longispinosus* eggs, and at humidity of 68% – 76.4% of larvae. At the same temperature and RH of 62%, 4.5% of larvae emerge from *N. californicus* eggs, and at RH of 68%, only 42.6% of larvae emerge.

When the temperature drops to 20 °C and at a humidity to 50%, only 5.5% of the larvae emerge from the eggs of *N. longispinosus*, while at a humidity of 68%, this indicator reaches 76.0% of the larvae emergence.

At temperature of 20 °C and humidity of 50%, 1.0% of larvae emerge from *N. californicus* eggs, and at a humidity of 68% only 49.6% of larvae emerge. A relative humidity of 70% is key to ensure success of embryonic development of predatory mites.

N. longispinosus – hatching of larvae reaches 92.6% (25 C) and 88.9% (at 20 C).

N. californicus – hatching of larvae reaches 50.1% (at 25) and 81.4% (at 20 C).

Table 5. Tolerance of ecological species of predatory mites to low air humidity.

Neoseiulus longispinosus		*Neoseiulus californicus*		Survival rate, %
20 °C	25 °C	20 °C	25 °C	
Relative air humidity, %				
60.7	68.3	68.4	72.4	50
66.5	73.6	74.1	79.4	75
75.6	78.5	79.4	86.1	90

It is important to note that *N. longyspinosus* larvae, without feeding, molt into protonymphs. *N. Longyspinosus* is evenly distributed through the leaf surface when resting (during the period of digestion of food and bearing egg production), in contrast to *N. californicus* (for example), which is concentrated near the leaf petiole.

Having penetrated into the colony of the phytophage, *N. longyspinosus* first destroys the age structure of the spider mite population, eating away the eggs of the prey. Daily gluttony is quite high. Each female predator destroys over 40 prey eggs, and this is more than 4 times higher than the daily fertility of female spider mite. As the density of eggs in the colony decreases, predators eat up all mobile prey individuals, including female spider mites.

5 Discussion

Some moisture concentrations of two types are tested under laboratory conditions. The data show the impact of humidity, however, after protective treatments on ornamental crops, different species of the same genus are identified Table 6. Variants of differences in resistance to drugs approved and promising for use in protected soil in Russia against the predatory mite *N. californicus* [11- 14]. The death of phytoseiids is assessed 24 hours after treatment with organophosphate insectoacaricides, after 72 hours with avermectins and neonicotinoids, and after 5 days with bitoxybacillin. Table 6 shows preparations for two types of mites. The list of pesticides and agrochemicals in the Russian Federation reveals the potential for possible use; practical research by chemical companies can expand their use. Studying both concentrations and standards for practical use [15], and comparing two types of mites of the same genus are very promising.

Table 6. Toxicity of insecto-acaricides for mite females.

Insecto-acaricides	**Active substance**	**Pesticide concentration, %**	**Female mortality, %**	
			Neoseiulus californicus	*Neoseiulus longispinosus*
Vertimek CE	abamectin, 8 g/l	0.05 *	100	92
Phytoverm CE	aversectin C, 2 g/l	0.2 *	100	91
Clipper CE	bifentrine, 100 g/l	0.08 *	100	–
Novaktion WE	malathion, 440 g/l	0.15 *	16.8	–
BTB P	BA-1500 CFU/mg *B. thuringiensis*	1.0 *	11.4	–
Actara WDG	thiamethoxam, 250 g/kg	0.08 *	10.7	–

[*] *concentrations of substances approved in Russia*

Previously, we established the risks of using pesticides in the fight against spider mites, pests of food, ornamental, and flower crops [16]. The combination of insecticides and fungicides for protection against pests and pathogens in the future requires the search for new compounds [17]. The importance of studying the transfer of pathogenic microflora by mites, which often causes diseases [18] is very promising. The influence of humidity and temperature has been poorly studied, and the combination of plant protection systems against various pests requires increased special knowledge. At the same time, the use of predatory mites significantly reduces pesticide loads on agrocenoses [19], [20].

Avermectin drugs and the pyrethroid Clipper are found to exhibit acute toxicity. The release of predatory mites is impossible during the use of avermectin and bifenthrin. The neonicotinoid Aktara, approved for the control of greenhouse whiteflies, as well as the insectoacaricides Bitoxibacillin and Novaktion had a lesser effect on predatory mites.

The limited range of acaricides, both in terms of active ingredients and factors of their routine use in individual countries, causes the formation of resistant populations of harmful mites. In the Russian Federation, the frequency and rate of application of pesticides are regulated by law, which is justified using the example of Flumite (the drug did not undergo large-scale testing).

Reliable basis for the effective use of predatory mites is the work of specialists. Knowledge of the mites biology, crops, production conditions and skillful calculations makes it possible to achieve goals without pesticides at a rapid rate of the predator population reproduction.

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