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LUCILLA SINGLEYANA (PILSBRY, 1890) AND *L. SCINTILLA* (R. T. LOWE, 1852) (GASTROPODA, PULMONATA, ENDODONTIDAE) IN THE CAUCASUS AND IN RUSSIA

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Abstract: Populations of *Lucilla singleyana* (Pilsbry) and *L. scintilla* (R. T. Lowe) were found in the Caucasus where they co-occurred in a bamboo grove. This is the first record of *L. singleyana* from the Caucasus and from Asia. In Ulyanovsk (European Russia), *L. singleyana* and *L. scintilla* were found together in houseplant pots. These are the easternmost populations of the species in Eurasia. The shells of *L. singleyana* and *L. scintilla* are very variable. The main difference between the species is the aperture form: in *L. singleyana* it is oval, and in *L. scintilla* it is rounded. In Ulyanovsk the shells of *L. singleyana* are smaller than in the Caucasus. The shells of *L. scintilla* in Ulyanovsk and in the Caucasus are equal in size. The biology of both species is similar. They live in the lower layers of litter and in the soil, to the depth of 50 cm, and in wet weather crawl up into the litter. They feed on decaying leaves, sprouting seeds and delicate grass. They lay eggs singly in the soil only in places with thin plant roots. The eggs are suspended on mucus threads, attached to the root hairs or to the ends of roots. *L. singleyana* and *L. scintilla* are potential greenhouse pests.

Key Words: *Lucilla singleyana, L. scintilla*, Endodontidae, autecology, alien species, Caucasus

INTRODUCTION

Lucilla singleyana (Pilsbry, 1890) and *Lucilla scintilla* (R. T. Lowe, 1852) are native to North America (Pilsbry 1948). In Europe they were first recorded from man-made habitats in the 20th century (Kuiper 1956, Flašar 1977, Horsák et al. 2004). Later, *L. singleyana* was found in natural and anthropogenic habitats of numerous European countries (Jauernig 1995, Juřičkova 1998, Čejka 2000, Rüetschi 2001, Čejka et al. 2006). Finding its shells in Quaternary deposits of Europe (Ložek 1964, Frank & Rabeder 1996) suggested that the species might be native at least in some parts of Europe (Schlickum 1979), but the problem requires further research.

L. singleyana is a soil-dweller. Combined with its small size, it makes it liable to introduction by humans. The species was brought to different countries with decorative plants. *L. singleyana* was imported to New Zealand where it soon became widespread (Barker 1999). In Russia it is found in greenhouses of flower farms in Moscow and Ulyanovsk (Schikov 2016).

L. scintilla was recorded from Germany, Poland, Slovakia, the Czech Republic and Ukraine (Kerney et al. 1983, Horsák et al. 2009, Stworzewicz 2013, Balashov 2016). Its precise distribution in Europe remains unclear. It is caused by the difficulty of finding the snails in the wild and by the fact that *L. scintilla* had long been confused with *L. singleyana*. Reliable differences between the two species were presented by Horsák et al. (2009). In this regard any data on the occurrence of *L. scintilla* in other countries appear to be important.

Ecological information on *L. singleyana* and *L. scintilla* is very scanty (Kerney 1999, Wiktor 2004, Stworzewicz 2013). The present work was aimed to investigate some aspects of their ecology.

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MATERIAL AND METHODS

This initial material for the study was collected by E. V. SHIKOV in Rostov-on-Don in 1986, and by R. R. GAINULLIN in Tsandripsh (Abkhazia) in 2010 and in Ulyanovsk in 2011 (Fig. 1). In Abkhazia *L. singleyana* and *L. scintilla* were found in the village of Tsandripsh (West Caucasus). *L. singleyana* and *L. scintilla* co-occurred in a bamboo grove (Figs 2, 3) located 200 m from the Black Sea coast (GAINULLIN & SCHIKOV 2012). In Rostov-on-Don two empty shells of *L. singleyana* were found in a container with a palm. In Ulyanovsk *L. singleyana* and *L. scintilla* were collected from houseplant soil. A total of 20 specimens of *L. singleyana* and 19 specimens of *L. scintilla* were collected. Live snails from Tsandripsh and Ulyanovsk were sent to me for ecological studies.

Fig. 1. European Russia and the Caucasus. Triangles – sites where *Lucilla* sp. were found

Experiments were conducted in 2011–2015 under laboratory conditions. The snails reproduced. Their offspring of the second and third generations were also included in the experiments, making a total of 80 specimens of *L. singleyana* and 65 specimens of *L. scintilla*. The snails were kept in round vivaria 10–12 cm in diameter and 8–12 cm in height. The bottom of the containers was covered with 3–6 cm thick layer of garden humus soil. For investigating the feeding habits, leaf litter (trees *Fraxinus excelsior* L., *Acer negundo* L., *Tilia cordata* Mill., *Malus domestica* Borkh. and shrubs *Rubus idaeus* L., *Rosa cinnamomea* L.) as well as wet seeds, sprouting seeds, fresh leaves, fruits, root vegetables were placed in the vivaria. Every day the soil surface and the plants were examined under stereo-microscope. To evaluate the maximum depth from which *L. singleyana* and *L. scintilla* could emerge

Figs 2–3. Bamboo grove: 2 – bamboo thickets stand out against the rest of vegetation, 3 – the soil surface in the bamboo grove (Photos: R. R. GAINULLIN)

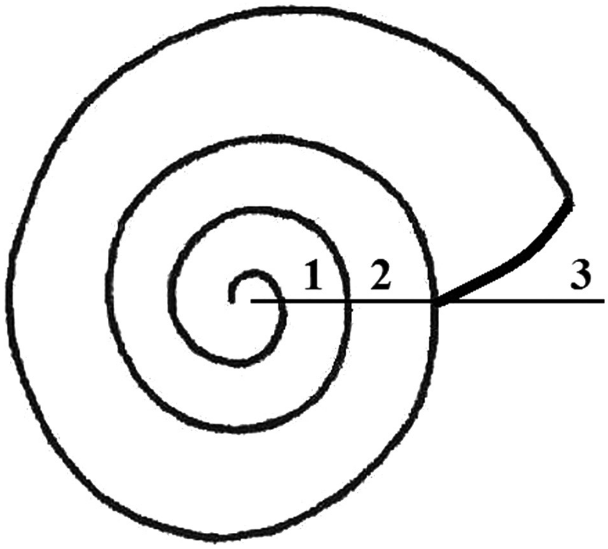


Fig. 4. Counting shell whorls

onto the surface for the night feeding, the snails were placed in a vivarium and covered with a layer of moist soil of a certain thickness. Plant damages were registered after 24 hours. The ability of *L. singleyana* and *L. scintilla* to withstand flooding was studied by putting them in tap water at room temperature. Their survivorship was analysed at 12 hour intervals. To determine the maximal depth of the snails' penetration into the soil, 30 specimens were placed in a wooden container (20×20×60 cm) filled with a 50 cm layer of garden soil. Its bottom was drilled for draining in case of heavy rainfall. A layer of leaf litter of 3 cm thickness was placed on the soil. The soil was inhabited by a few earthworms. The box was dug into the garden soil and left there from May to June 2014, then it was dug out and the soil was checked for the presence of *L. singleyana* and *L. scintilla* layer by layer. The snails were photographed and their shells measured under a stereo-microscope MBS-10. The whorls were counted as shown in Fig. 4.

RESULTS

In Abkhazia *L. singleyana* and *L. scintilla* inhabited the top layer of soil in an abandoned bamboo (*Phyllostachys aurea)* grove (Figs 2, 3) planted 35 years ago. Both *L. singleyana* and *L. scintilla* were abundant. The two populations co-existed in the same habitat. Numerous empty shells showed that the populations had lived there for many years. *Sieversia lederi* (O. Boettger, 1881) and *Oxychilus* sp. were found together with *L. singleyana* and *L. scintilla*.

Shells of *L. singleyana* and *L. scintilla* were of different colour. The shell measurements of *L. singleyana* and *L. scintilla*'s from Tsandripsh and Ulyanovsk are given in Tables 1 and 2, respectively. *L. singleyana* had a low spire, with whorls not flattened, and not always evenly increasing. The last part of the body whorl was usually descending, the aperture roundish, with its upper edge usually sharply curved (Figs 5–10). The shells of *L. singleyana* from Tsandripsh and from Ulyanovsk differed significantly (Table 3). *L. scintilla* has a low-spired shell, with whorls not always increasing evenly, not flattened, usually descending before the aperture. The aperture is round, with its upper edge usually sharply curved. The typical form of *L. scintilla* is shown in Figs 11–13, and its variation is presented in Figs 14–25. The conchological differences between *L. scintilla* from Tsandripsh and from Ulyanovsk were not significant (Table 3).

The bodies of *L. singleyana* and *L. scintilla* are of the same colour. They are light grey (Figs 26–31, 35). The nuances of body colour depend on lighting. In

Table 1. Statistical indices of populations of *Lucilla singleyana*: N – number of specimens, x – arithmetic mean, s – standard deviation, x_s – range limits of the standard deviation, b – standard error, x_b – range limits of the standard error, Mn – minimum value, Mx – maximum value

Statistical indices	N	x	s	X_{s-}–X_{s+}	b	X_{b-}–X_{b+}	Mn	Mx
Tsandripsh								
Shell height	12	1.11	0.03	1.05–1.17	0.01	1.09–1.13	1.05	1.17
Shell diameter	12	2.55	0.14	2.27–2.83	0.04	2.51–2.63	2.35	2.8
Aperture height	12	0.85	0.04	0.77–0.93	0.01	0.83–0.87	0.8	0.9
Aperture breadth	12	1.05	0.04	0.97–1.13	0.01	1.03–1.07	1.0	1.1
Number of whorls	12	3.6	0.19	3.22–3.98	0.06	3.48–3.98	3.3	4.0
Ulyanovsk								
Shell height	9	0.93	0.08	0.77–1.09	0.03	0.87–0.99	0.83	1.05
Shell diameter	9	2.12	0.16	1.8–2.44	0.05	2.02–2.22	1.95	2.37
Aperture height	9	0.74	0.04	0.66–0.82	0.01	0.72–0.74	0.65	0.8
Aperture breadth	9	0.88	0.08	0.72–1.04	0.03	0.82–0.94	0.8	1.0
Number of whorls	9	3.23	0.2	2.83–3.63	0.07	3.09–3.37	2.95	3.5

Table 2. Statistical indices of populations of *Lucilla scintilla*: N – number of specimens, x – arithmetic mean, s – standard deviation, x_s – range limits of the standard deviation, b – standard error, x_b – range limits of the standard error, Mn – minimum value, Mx – maximum value

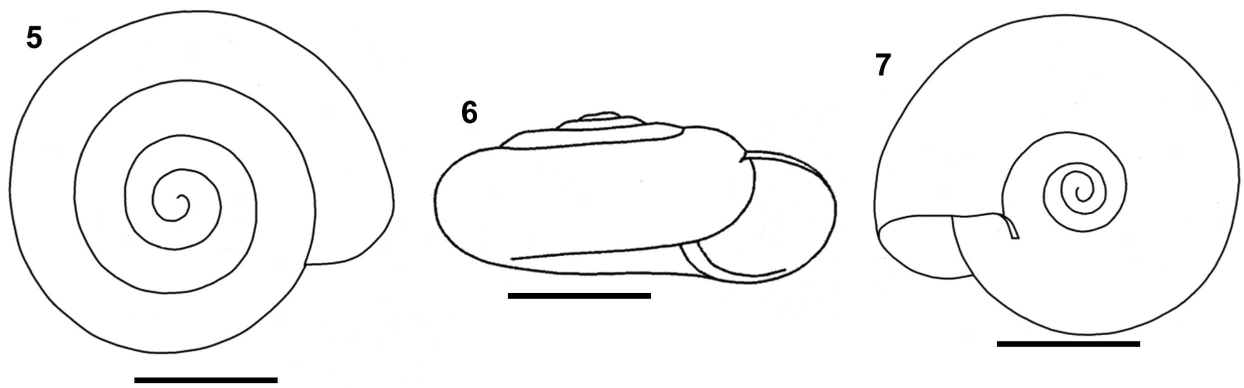
Statistical indices	N	x	s	X_{s-}–X_{s+}	b	X_{b-}–X_{b+}	Mn	Mx
				Tsandripsh				
Shell height	8	0.97	0.1	0.77–1.17	0.04	0.89–1.05	0.83	1.07
Shell diameter	8	2.2	0.19	1.82–2.58	0.07	2.06–2.34	1.95	2.4
Aperture height	8	0.75	0.04	0.67–0.83	0.01	0.73–0.77	0.7	0.8
Aperture breadth	8	0.85	0.09	0.67–1.03	0.03	0.79–0.91	0.75	0.95
Number of whorls	8	3.3	0.16	2.98–3.62	0.06	3.18–3.42	3.1	3.5
				Ulyanovsk				
Shell height	10	1.0	0.04	0.92–1.08	0.1	0.8–1.2	0.9	1.0
Shell diameter	10	2.1	0.09	1.92–2.28	0.03	2.04–2.16	1.97	2.25
Aperture height	10	0.75	0.02	0.71–0.79	0.01	0.73–0.77	0.7	0.8
Aperture breadth	10	0.89	0.04	0.81–0.97	0.01	0.87–0.91	0.85	0.95
Number of whorls	10	3.2	0.04	3.12–3.28	0.01	3.18–3.22	3.1	3.25

Table 3. Comparison of shells of *Lucilla singleyana* and *L. scintilla* from the populations in the village of Tsandripsh and in the city of Ulyanovsk. X_1 – Tsandripsh, X_2 – Ulyanovsk. Ds – difference significant, Dns – difference not significant

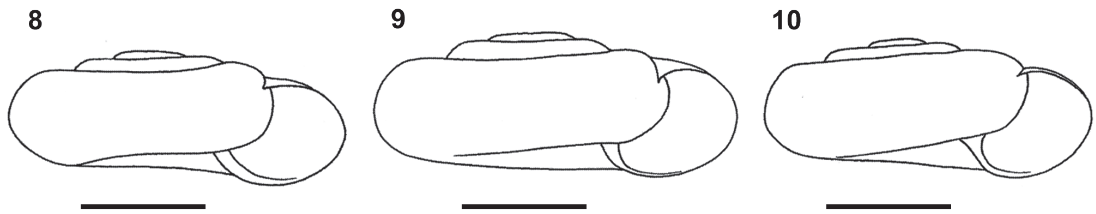
				Lucilla singleyana			
	$X_1 - X_2$	b_1^2	b_2^2	$b_1^2 + b_2^2$	$\sqrt{b_1^2 + b_2^2}$	$X_1 - X_2$ / $\sqrt{b_1^2 + b_2^2}$	conclusion
Shell height	0.18	0.0001	0.0009	0.001	0.03	6	Ds
Shell diameter	0.43	0.0016	0.0025	0.0041	0.064	6.7	Ds
Aperture height	0.11	0.0001	0.0001	0.0002	0.014	7.9	Ds
Aperture breadth	0.17	0.0001	0.0009	0.001	0.03	5.6	Ds
Number of whorls	0.37	0,0036	0,0049	0.0082	0.09	4.1	Ds
				Lucilla scintilla			
	$X_1 - X_2$ $X_2 - X_1$	b_1^2	b_2^2	$b_1^2 + b_2^2$	$\sqrt{b_1^2 + b_2^2}$	$X_1 - X_2$ / $\sqrt{b_1^2 + b_2^2}$	conclusion
Shell height	0.03	0.0016	0.01	0.0116	0.04	0.75	Dns
Shell diameter	0.1	0.0049	0.0009	0.0058	0.076	1.3	Dns
Aperture height	0	–	–	–	–	–	–
Aperture breadth	0.04	0.0009	0.0001	0.001	0.03	1.3	Dns
Number of whorls	0.1	0.0036	0.0001	0.0037	0.06	1.6	Dns

strong light from above the body is almost translucent (Fig. 28). At medium light it is greyish white (Fig. 29). In Fig. 35 the light is natural, lateral, from the window. The body looks grey and the skin texture is well-visible.

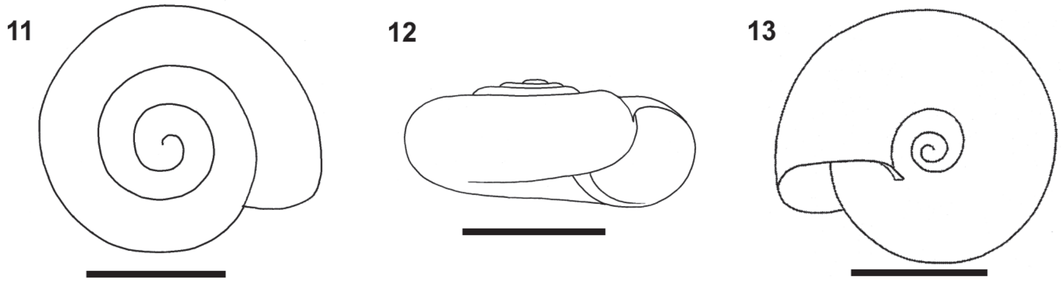
The studied biological features of *L. singleyana* and *L. scintilla* were similar. Both species were found to inhabit soil and the lower layer of leaf litter, penetrating to the depth of up to 50 cm, using earthworm tunnels. Young and adult *L. singleyana* and *L. scintilla*



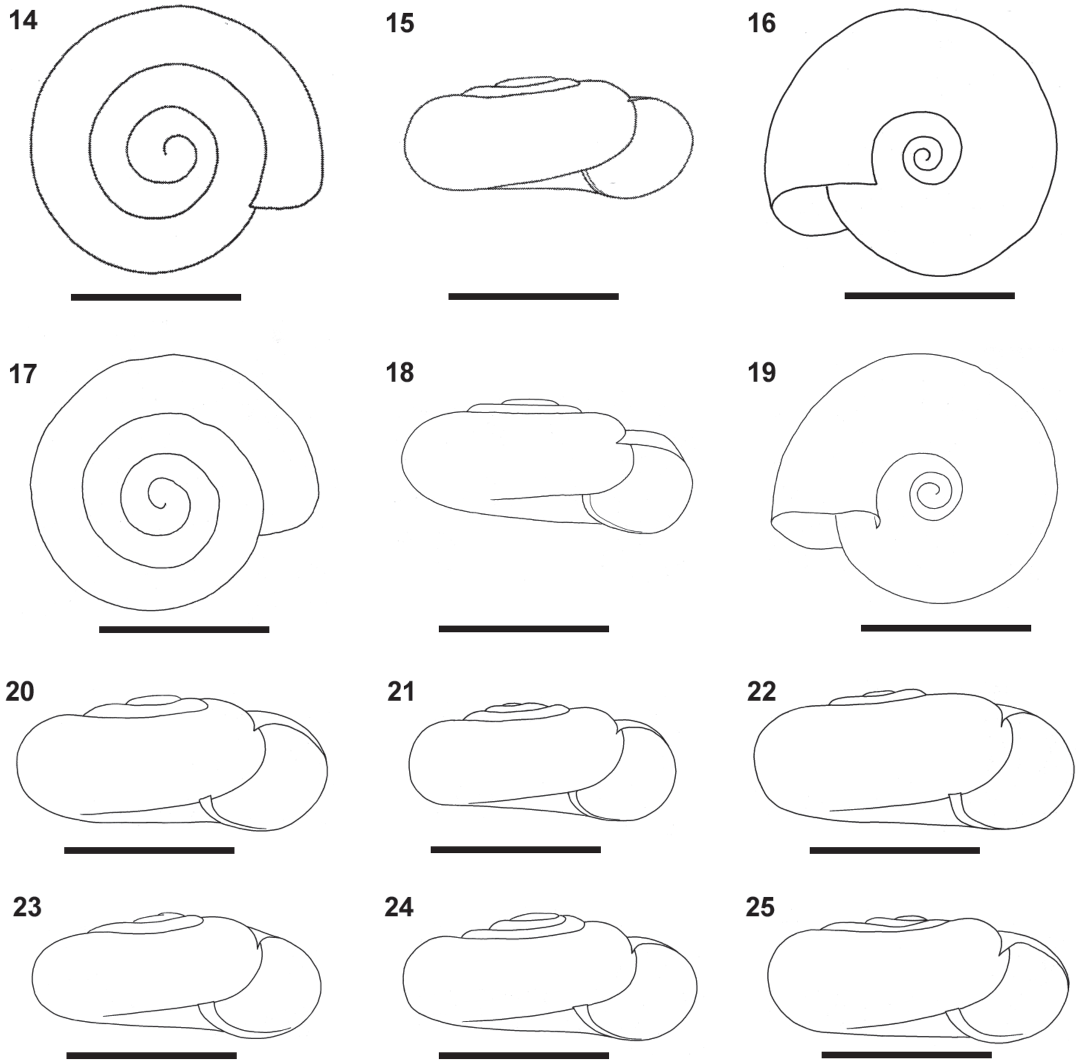
Figs 5–7. Typical shell of *Lucilla singleyana*. Caucasus, Abkhazia, settlement Tsandripsh (North-West of Sukhumi). 2010, leg. Gainullin R. R., det. Schikov E. V. Scale bar 1 mm



Figs 8–10. Shell variation in *Lucilla singleyana*. Caucasus, Abkhazia, settlement Tsandripsh (North-West of Sukhumi). 2010, leg. GAINULLIN R. R., det. SCHIKOV E. V. Scale bar 1 mm

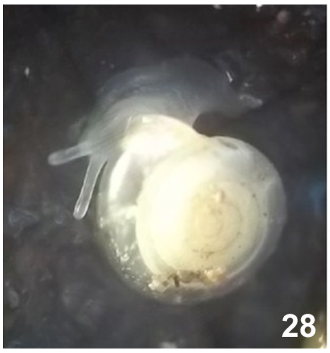


Figs 11–13. Typical shell of *Lucilla scintilla*. Caucasus, Abkhazia, settlement Tsandripsh (North-West of Sukhumi). 2010, leg. GAINULLIN R. R., det. SCHIKOV E. V. Scale bar 1 mm



Figs 14–25. Shell variation in *Lucilla scintilla* shells. Caucasus, Abkhazia, settlement Tsandripsh (North-West of Sukhumi). 2010, leg. GAINULLIN R. R., det. SCHIKOV E. V. Scale bar 1 mm

Figs 26–27. *Lucilla singleyana* (the arrow points to the very small eye) (Photos: R. R. GAINULLIN)



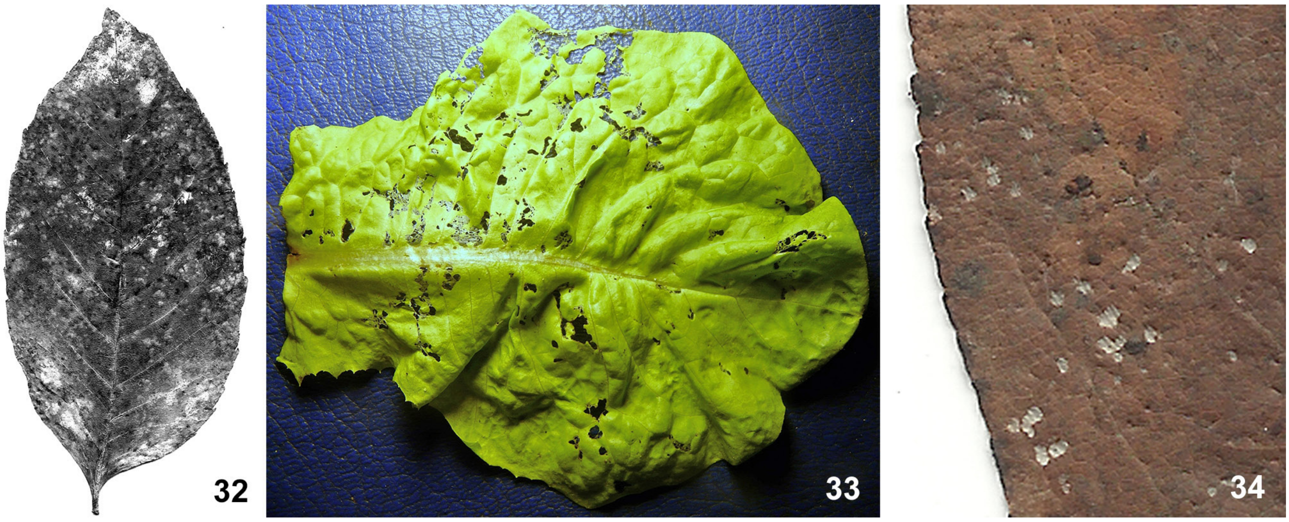
Figs 28–29. *Lucilla singleyana*: 28 – bright illumination from above (Photo: E. V. SCHIKOV), 29 – moderate illumination from above (Photo: R. R. GAINULLIN)

tended to prefer decaying wood. Soaked rotting timber retains dampness for a long time even during periods of drought, thus saving the snails from drying out (SCHIKOV 1980) (Figs 26–28).

L. singleyana and *L. scintilla* were observed to feed on decaying plant debris and on delicate tissues of live plants. The snails ate away the surface tissues of sodden leaves. They could gnaw very small holes in them, but more often they only "rarefied" the leaf making it slightly translucent (Fig. 32). The experiments showed that *L. singleyana* and *L. scintilla* might damage lettuce by gnawing small holes in its leaves (Fig. 33). *L. singleyana* and *L. scintilla* damaged delicate root ends, seeds and sprouting seeds of a variety of herbaceous plants (families Cruciferae and Leguminosae). They also ate germinated seeds of hemp, cucumber, carrot, lettuce, peppers, eggplant, flesh of cucumber, carrot, lettuce leaves, and rain-sodden bamboo leaf litter. They almost completely consumed seeds of many of the mentioned plants and severely damaged seedlings (Fig. 35).

L. singleyana and *L. scintilla* displayed a negative phototaxis. At nights, when the humidity was high, they crawled up to the soil to feed and mate. Emerging from the depth of 3 cm, they found their preferred plants by smell. At high soil and leaf litter humidity copulation occurred in the lower layer of litter. At high air humidity *L. singleyana* and *L. scintilla* were observed to copulate on the soil surface. The presence of thin delicate roots of live plants was essential for both species. The snails laid eggs singly and always near delicate roots (Figs 36–40). In the absence of live roots in the soil, *L. singleyana* and *L.*

Figs 30–31. *Lucilla scintilla* (31 – on decaying leaves) (Photos: E. V. SCHIKOV)



Figs 32–34. Leaves damaged by *Lucilla singleyana*: 32 – fragment of *Fraxinus excelsior* leaf, 33 – lettuce, 34 – fragment of old apple leaf

scintilla failed to lay eggs. The oviposition was accompanied by a sustained secretion of mucus from the atrium. The mucus completely covered each egg and followed it as a thin thread. Thus, during the oviposition each egg was already hanging on a mucous thread. When laying eggs, the snail moved slowly and the mucous thread was accidentally glued to the surrounding soil, so that the egg hung on the thread in the space between soil particles (Figs 36, 40). The snails were attracted by the youngest fine roots and root hairs; they turned to them and the eggs became glued to the root hairs (Figs 37–39). The oviposition was facilitated by the high mobility of the snails' bodies: holding the shell motionless, they could turn their head and foot by 180° (Fig. 27). Freshly laid eggs were completely translucent (Fig. 37); they became opaque later (Figs 38–40). The eggs were spherical or nearly so. In the attachment points of the mucus threads, mucous cones were formed (Fig. 40). The egg diameter was 0.55–0.67 mm (n = 6) in *L. singleyana* and 0.4 mm (n = 2) in *L. scintilla*.

L. singleyana withstood up to 72 hours under water and *L. scintilla* – up to 48 hours. This helps the snails to survive a long time of flooding during rains or abundant irrigation of pot plants. In vivaria, *L. singleyana* superseded *Vallonia pulchella* (O. F. Müller, 1774) and *V. costata* (O. F. Müller, 1774), but the reasons for his are unknown. There was no shortage of food. In large containers with plants *L. singleyana* and *L. scintilla* could live together with *V. pulchella* and *V. enniensis* (Gredler, 1856).

Fig. 35. *Lucilla scintilla* eating a cucumber leaf. (Photo: E. V. SCHIKOV)

Fig. 36. Egg of *Lucilla singleyana* on mucus threads. Diameter 0.57 mm. Scale bar 1 mm. (Photo: E. V. SCHIKOV)

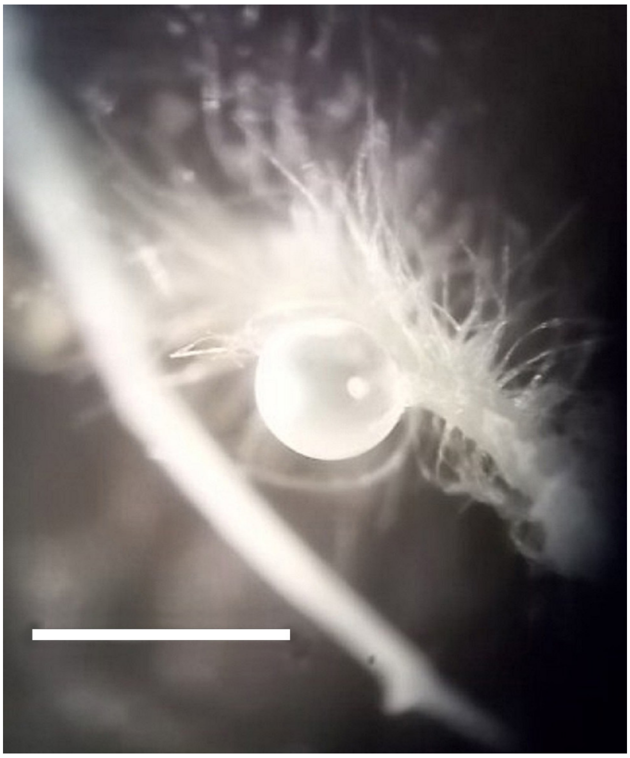


Fig. 37. Egg of *Lucilla singleyana* on root hairs. Diameter 0.55 mm. Scale bar 1 mm. (Photo: E. V. SCHIKOV)

Fig. 39. Egg of *Lucilla singleyana* on root hairs. Diameter 0.56 mm. Scale bar 1 mm. (Photo: E. V. SCHIKOV)

IDENTIFICATION REMARKS

L. scintilla and *L. singleyana* are conchologically similar, but some differences can be noticed.

In *L. singleyana* the shell is colourless, larger, with the maximum diameter of 2.0–3.0 mm, and the umbilicus is slightly wider; the aperture is oval and markedly expanded to the right (Figs 5–10). The shell surface bears a very fine spiral striation, well seen at 45× magnification. However, HORSÁK et al. (2009) mentioned that the spiral striation was not characteristic of every population of *L. singleyana*.

In *L. scintilla* the shell is yellowish, of the maximum diameter of 2.0–2.4 mm, the whorls not flattened, the aperture roundish, and there is no spiral striation on the surface. The yellowish colour of young *L. scintilla* is weakly pronounced and cannot be used as a reliable character. At puberty, the columellar edge becomes reflected and the aperture acquires its characteristic shape.

L. singleyana and *L. scintilla* are similar to *Vallonia pulchella* and to *Vallonia excentrica* Sterki in Pilsbry,

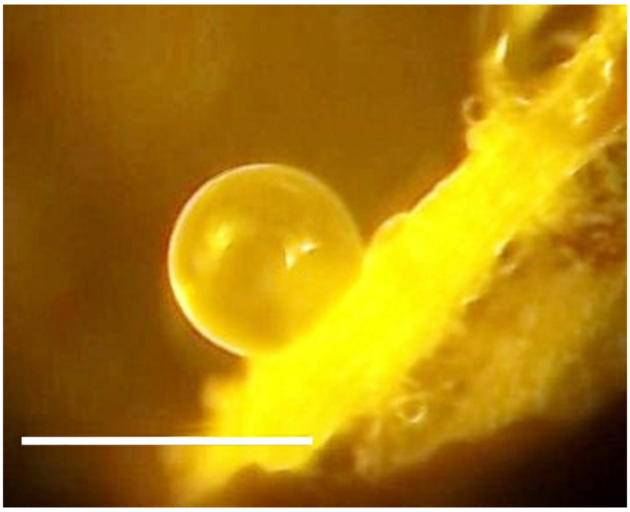


Fig. 38. Egg of *Lucilla singleyana* on a root tip. Diameter 0.67 mm. Scale bar 1 mm. (Photo: E. V. SCHIKOV)

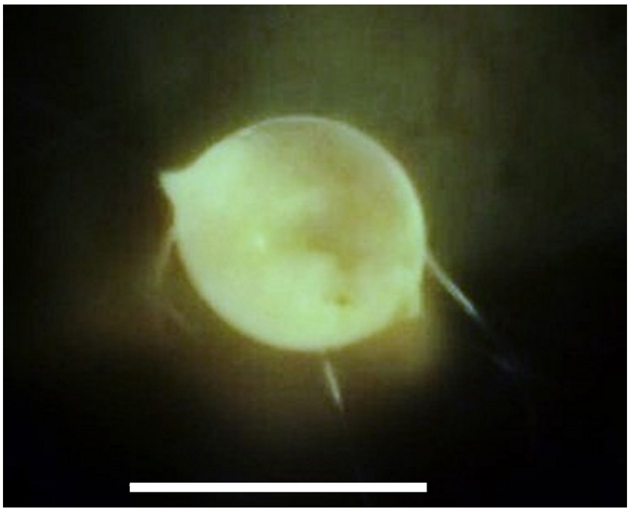


Fig. 40. Egg of *Lucilla scintilla* on mucus threads. Diameter 0.40 mm. Scale bar 0.5 mm. (Photo: E. V. SCHIKOV)

1893. They differ in the following characters. The shells of *L. scintilla* and *L. singleyana* are thinner and transparent. Their whorls are gradually expanding. In *Vallonia* the body whorl abruptly expands before the aperture; this expansion forms the lip. In *L. singleyana* and *L. scintilla* there is no expansion of the body whorl before the aperture and thus no lip. The mantle edge in *L. singleyana* is light-red. In *L. scintilla* this is difficult to notice because of the coloured shell, or the character is not expressed at all. In *Vallonia* the mantle edge is light-grey. *Vallonia* have clearly visible eyes. In *L. singleyana* and *L. scintilla* the eyes are very small and hardly noticeable (Figs 27, 31).

L. singleyana and *L. scintilla* differ from *Vitrea contracta* (Westerlund, 1871) in a much broader umbilicus. They are also similar to *Hawaiia minuscula* (Binney, 1841). The differences between *L. singleyana* and *H. minuscula* were listed by Bodon et al. (2004). The shell of *Lucilla* is smooth, with a poorly visible spiral sculpture on a surface. The shell surface of *H. minuscula* bears a distinct spiral sculpture. The aperture in *H. minuscula* is round like that of *L. scintilla*, but the shell is colourless. *L. singleyana* differs from *H. minuscula* in its oval aperture.

The eggs of *L. singleyana* and *L. scintilla* are spherical or nearly spherical (Figs 36–40), and those of *Vallonia* are discoid. In *V. pulchella* the diameter of the egg disc is 0.6–0.7 mm, the thickness is 0.5–0.6 mm (n = 27).

DISCUSSION

The shell shape of *L. singleyana* from Tsandripsh corresponded with the conspecific shells from the Czech Republic and Slovakia (Horsák et al. 2009). Some shells were smaller. The shells of *L. scintilla* were smaller than those from Europe and the USA (Baker 1929, Horsák et al. 2009) and more variable. It was probably the result of living in the humid sub-tropical climate of Abkhazia. Co-occurrence of *L. singleyana* and *L. scintilla* without any intermediate forms confirms their distinct specific status. Differences in the egg size between *L. singleyana* and *L. scintilla* were not presented because of the small number of examined eggs.

L. singleyana and *L. scintilla* damage house plants; they are also potential pests of crops in greenhouses. The laboratory studies revealed that in industrial greenhouses *L. singleyana* might damage lettuce. Thus, it is recommended to include both species in the list of quarantine pests.

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