



Revision of the *Myelochroa* genus (Parmeliaceae, lichenized Ascomycota) in the south of the Russian Far East

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ABSTRACT

A revision of the genus *Myelochroa* in the south of Russian Far East was carried out. A total of eight species of the genus were identified, and a key for their identification was prepared. For each species, the characteristic features of the studied samples, differences from related species are indicated, their distribution was clarified, and maps were prepared. Several new substances were identified during the study of the composition of secondary metabolites of *Myelochroa* species. Chloroatranorin was reported for the genus *Myelochroa* for the first time. In addition, noristic acid was found for the first time in *M. galbina* and *M. metarevoluta*, and salazinic acid was found for the first time in *M. leucotyliza*. The taxonomic significance of some substances in the systematics of the genus has been clarified.

Keywords: lichens, Asia, Parmeliaceae, secondary metabolites, distribution, taxonomy

РЕЗЮМЕ

Чесноков С.В., Конорева Л.А., Прокопьев И.А., Скирин Ф.В., Скирина И.Ф. Ревизия рода *Myelochroa* (Parmeliaceae, lichenized Ascomycota) на юге Дальнего Востока России. Проведена ревизия рода *Myelochroa* на юге российского Дальнего Востока. Всего было выявлено восемь видов рода, подготовлен ключ для определения. Для каждого вида указаны характерные особенности изученных образцов, отличия от близких видов, уточнен ареал и составлены карты распространения видов. При изучении состава вторичных метаболитов видов *Myelochroa* выявлен ряд новых веществ. Впервые для рода *Myelochroa* указан хлороатранорин. Кроме того, у *M. galbina* и *M. metarevoluta* впервые обнаружена норстиктовая кислота, а у *M. leucotyliza* – салациновая кислота. Уточнено таксономическое значение некоторых веществ в систематике рода.

Ключевые слова: лишайники, Азия, Parmeliaceae, вторичные метаболиты, распространение, систематика

The genus *Myelochroa* was separated by Elix & Hale (1987) from a morphologically similar genus *Parmelina* Hale on the basis of the yellow medulla (production of secalonic acid A and related compounds) and the East Asian–North American distribution. In addition, *Myelochroa* species are characterized by closely appressed thalli with narrow lobes, simple and short cilia, sparse or dense, usually restricted to the sinuses of the lobes, and bifusiform or bacilliform conidia. Phylogenetic studies by Núñez-Zapata et al. (2017) confirmed that the *Myelochroa* genus is independent, monophyletic and closely related to *Parmelina*. There are currently about 30 species of *Myelochroa* species worldwide (Elix & Hale 1987, Elix 1996, DePriest & Hale 1998, Divakar et al. 2001a, b, Wang et al. 2001, Marcelli & Canêz 2008, Otnyukova et al. 2009, Crespo et al. 2010).

According to Kurokawa & Arakawa (1997), all species of the genus can be divided into three groups based on the presence or absent of galbinic acid, triterpenoids and moniliform cells in the medulla. *Myelochroa galbina* group includes *M. galbina* (Ach.) Elix & Hale, *M. hayachinensis* (Kurok.) Elix & Hale, *M. metarevoluta* (Asahina) Elix &

Hale, *M. obsessa* (Ach.) Elix & Hale and two species from Siberia (Otnyukova et al. 2009) – *M. sibirica* Otnyukova, Stepanov & Elix and *M. sayanensis* Otnyukova, Stepanov & Elix, and is characterized by the presence of the galbinic acid, triterpenoids and moniliform cells in the medulla. The second group, *M. aurentata* group includes most species of the genus and is characterized by the presence of triterpenoids and absent of galbinic acid and moniliform cells in the medulla. The *M. immiscens* group does not produce galbinic acid and triterpenoids and does not form moniliform cells in the medulla. The third group, which includes *M. immiscens* (Nyl.) Elix & Hale and *M. lindamanii* (Lyng.) Elix & Hale, was assigned Kurokawa & Arakawa (1997) to the genus *Parmotrema* A. Massal. For *Myelochroa lindamanii*, the belonging to the genus *Parmelinella* Elix & Hale was proved in recent studies (Eliasaro et al. 2010, Rodrigues et al. 2021).

Despite the wide distribution of genus *Myelochroa* in Asia (Hale 1976, Kurokawa & Arakawa 1997, Jayalal et al. 2012, Moon et al. 2015) and North America (Hale 1976), the last revision in Russia was carried out by 1971, when

the first volume of the “Handbook of Lichens of the USSR” was published, where the genus was considered within the genus *Parmelia* Ach. (Rassadina 1971). In total, in this work Rassadina (1971) reports five species – *M. aurulenta* (Tuck.) Elix & Hale, *M. entotheiochroa* (Hue) Elix & Hale, *M. metarevoluta*, *M. perisidians* (Nyl.) Elix & Hale and *M. subaurulenta* (Nyl.) Elix & Hale. *Parmelia homogenes* Nyl. was later synonymized with *M. subaurulenta* (Kurokawa & Arakawa 1997). Later, Otnyukova et al. (2009) described two new species – *M. sibirica* and *M. sayanensis*. *Myelochroa leucotyliža* (Nyl.) Elix & Hale in the south of the Russian Far East is reported by Tchabanenko (2014) and Ezhkin (2019). In 2022, the first two authors of this paper processed the *Myelochroa* genus using morphological data (Chesnokov & Konoreva 2023). As a result of this investigation, *M. galbina* and *M. hayachinensis* were identified for the first time in Russia. Thus, ten species of *Myelochroa* were known for Russia by the beginning of our research, eight of which are known mainly in the south of the Russian Far East. These species belong to the *Myelochroa galbina* and *M. aurulenta* groups.

In this paper, we present more detailed information on the composition of secondary metabolites, distribution and some features of the studied material that were not included in the previous study (Chesnokov & Konoreva 2023).

MATERIAL AND METHODS

Sampling

This study is based on revisions of herbarium material in Komarov Botanical Institute RAS (LE) and Pacific Institute of Geography FEB RAS (VGEO). The doublet specimens have been deposited in the herbaria of the Botanical Garden-Institute FEB RAS (VBGI) and Polar-Alpine Botanical Garden-Institute KSC RAS (KPABG). The material was examined using standard microscopic techniques (Smith et al. 2009, Stepanchikova & Gagarina 2014) using a binocular stereoscopic microscope Motic SMZ-171-LED and a standard set of chemical reagents (K – 10 % KOH, C – calcium hypochlorite, P – alcohol solution of p-para-phenylenediamine) for carrying out color spots reactions. A total of about 1300 specimens from the genus *Myelochroa* were studied.

Photographs of the species were taken with a stereoscopic microscope Motic SMZ-171-LED with an attached MotiCam S6 camera. Geographical coordinates are given in the system WGS 1984. The maps were created in the Arc GIS Pro program using built-in backgrounds and then refined in a vector editor. Nomenclature of vascular plants corresponds to ‘The World Checklist of Vascular Plants (WCVP) database’ (<https://powo.science.kew.org/about-wcwp>).

Chemical analyses

For the analysis, freeze dried lichen thalli were ground in a mortar. 5 mg of the resulting powder were extracted with 1 ml of acetone. The extraction was carried out with constant stirring for 24 hours at a temperature of 20–25°C. The obtained extracts were centrifuged at 15 000 g for 5 min and then kept at 4°C until analysis.

High-performance liquid chromatography (HPLC) analysis was performed on the LicArt 62 chromatograph (Labconcept, Russia), equipped with a diode-array detector (DAD). For chromatographic separation, the Agilent Zorbax SB-Aq C18 column (150 × 2.1 mm, 3.5 µm) was used. The mobile phase consisted of (A) water: acetonitrile: formic acid (95:5:0.1 v/v), and (B) acetonitrile: water: formic acid (90:10:0.1 v/v). Analyses were performed at 30°C and a flow rate of 0.3 ml/min in the gradient elution mode, the percentage of B was programmed as follows: 5 % (2 min) – 50 % (5 min) – 70 % (15 min) – 100 % (25 min) – 100 % (35 min). The volume of the injected sample was 5 µL. UV spectra were recorded in the range 190–400 nm using the DAD. Identification was carried out by comparing the retention times (Rt) and UV spectra of the peaks in the chromatogram with the peaks of the authentic standards of substances from the Komarov Botanical Institute collection.

To detect the presence or absence of triterpenoids, the thin-layer chromatography (TLC) analysis was performed with using TLC Silica gel 60 Merck (Germany) plates and solvent systems A and C (Orange et al. 2001). Triterpenoids reference standards were used as controls. After chromatographic development, the plates were sprayed with a 10 % sulphuric acid solution and heated at 100°C for 15 min. Finally, the plates were cooled to room temperature and studied in daylight.

RESULTS

Myelochroa aurulenta (Tuck.) Elix et Hale (Fig. 1A, B)

Myelochroa aurulenta is characterized by the presence of laminar to subterminal soralia, with farinose to granular soredia, which form from destroyed pustules, a yellow orange medulla and negative reactions of the medulla on all spot tests. Apothecia rare, usually have a sorediose thallus margin. It is interesting to note that in some specimens capitate soralia with farinose soredia predominate (Fig. 1A), whereas in others the soralia are laminar, shapeless, often diffuse and merging with granular soredia (Fig. 1B).

The studied specimens of *M. aurulenta* (about 400) were often represented by a mixture of several species. In most cases, *M. leucotyliža*, *M. metarevoluta* and *M. hayachinensis* were noted in addition to *M. aurulenta*. These species have sometimes been mistakenly identified as *M. aurulenta*. *Myelochroa metarevoluta* and *M. hayachinensis* belong to the *M. galbina* group and are easily distinguished by the presence of galbinic acid (P+ orange) and moniliform cells in the medulla. The pustules of *M. leucotyliža* are often clustered, which may cause them to resemble the soralia of *M. aurulenta*; the eroded margins of the pustules resemble granular soredia, but true soredia never form.

A study of lichen acids in randomly selected samples from different regions revealed the presence of the chemotype with leucotylic acid (Table 1). According to literary data (Kurokawa & Arakawa 1997, Moon et al. 2015), this chemotype is more common and widespread than the leucotylin chemotype. Additionally, chloroatranorin, which has not been previously reported in the literature, was detected in all studied samples.

Chemistry: atranorin (M), chloroatranorin (m), secalonic acid A (M), zeorin (m), leucotylic acid (m).

Distribution in the Russian Far East: The species is widespread in the south of the Russian Far East: Amur Region, Jewish Autonomous Region, Khabarovsk and

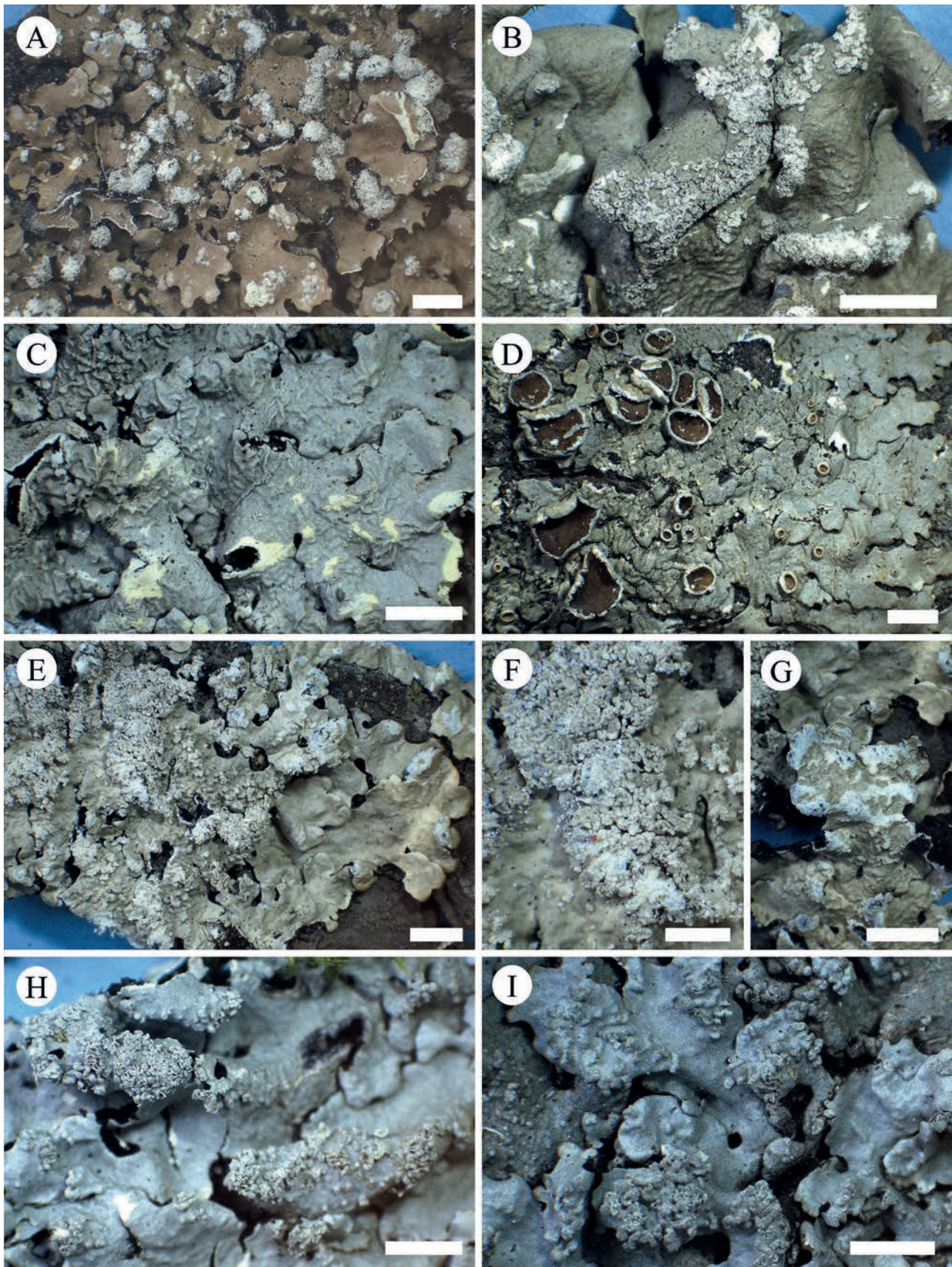


Figure 1 *Myelochroa* species: A – *M. aurulenta* (Tuck.) Elix et Hale with subterminal soralia, B – *M. aurulenta* with laminal soralia, C – *M. entothelochroa* (Hue) Elix et Hale, D – *M. galbina* (Ach.) Elix et Hale, E – *M. hayachinensis* (Kurok.) Elix et Hale, F – clusters of pustules of *M. hayachinensis* resembling soralia, G – fragile upper surface of *M. hayachinensis*, H – *M. leucotyliza* (Nyl.) Elix et Hale, I – pustules of *M. leucotyliza*. Scale bar: A, D, E, I – 2 mm, B, C, G, H – 3 mm, F – 1 mm

Table 1. A comparison of the content of secondary metabolites in *Myelochroa* lichens from different authors.

<i>Myelochroa</i> species	Source	Secondary metabolites									
		atranorin	chloroatranorin	zeorin	leucotylin	leucotylic acid	galbinic acid	norstictic acid	salazinic acid	secalonic acid A	constictic acid
<i>M. aurulenta</i>	O	+	+	+	-	+	-	-	-	+	-
	H	+	+	+	-	+	-	-	-	+	-
	KA	+	-	+	+/-	+/-	-	-	-	+	-
	J	+	+	+	+	+	-	-	-	+	-
<i>M. entotheiochroa</i>	O	+	+	+	+	+	-	-	-	+	-
	H	+	+	+	+	+	-	-	-	+	-
	KA	+	-	+	+/-	+/-	-	-	-	+	-
	J	+	+	+	+	+	-	-	-	+	-
<i>M. galbina</i>	O	+	+	+	-	+	+	+/-	+	+/-	-
	H	+	+	+	+	+	-	-	+	+	-
	KA	+	-	+	+/-	+/-	+	-	+	+	-
	J	+	+	+	+	+	-	-	+	+	-
<i>M. hayachinensis</i>	O	+	+	+	-	+	-	+	+	+/-	-
	H	+	+	+	+	+	-	-	-	-	-
	KA	+	+	+	+	+	-	-	-	-	-
	J	+	+	+	+	+	-	-	+	+	-
<i>M. leucotyliza</i>	O	+	+	+	+	+	-	-	+	+	-
	H	+	+	+	+	+	-	-	+	+	-
	KA	+	-	+	+	+	-	-	-	+	-
	J	+	+	+	+	+	-	-	-	+	-
<i>M. metarevoluta</i>	O	+	+	+	-	+	+	+	+	+/-	-
	H	+	+	+	+	+	-	-	+	+	+
	KA	+	-	+	+	+	-	-	-	+	-
	J	+	+	+	+	+	-	-	+	+	-
<i>M. perisidians</i>	O	+	+	+	+	+/-	-	-	-	+	-
	H	+	+	+	+	+	-	-	-	+	-
	KA	+	-	+	+	+/-	-	-	-	+	-
	J	+	+	+	+	+	-	-	-	+	-
<i>M. subaurulenta*</i>	O	+	+	+	+	+	-	-	+	+	-
	H	+	+	+	+	+/-	+	-	-	+	-
	KA	+	-	+	+/-	+/-	-	-	-	+	-
	J	+	+	+	+	+	-	-	-	+	-
<i>Myelochroa</i> sp.	O	+	+	+	+	-	-	-	-	+	-

Note: O – authors own observations, H – Hale (1976), KA – Kurokawa & Arakawa (1997), J – Jayalal et al. (2012), M – Moon et al. (2015); * – data from the literature are given for *M. subaurulenta* s. lat.; “+” – substance present, “-” – substance absent.

Primorye territories, Sakhalin Region (Sakhalin, Kunashir and Shikotan islands) (Fig. 2A). The northern boundary of the range apparently runs in the south of Khabarovsk Territory and the southern part of Sakhalin Island.

Selected examined specimens: AMUR REGION, Zeisky District, Zeysky Reserve, Tukuringra Ridge, 54°07'54"N 126°43'44"E, alt. 583 m, spruce forest, on bark of *Salix cardiophylla*, 16.08.2016, S.V. Dudov z201, det. E.S. Kuznetsova (L.E.L-18173). JEWISH AUTONOMOUS REGION, Obluchensky District, Maly Khingan Range, 16 km north of Lagar-Aul village, north-west slope, 49°15'42.8"N 132°21'11.1"E, alt. 670 m, fir-spruce forest, on bark of *Betula costata*, 13.06.2018, I.F. Skirina, det. F.V. Skirin (VGEO 35673); Smidovichsky District, Bastak Nature Reserve, Zabelovskiy area, near Zabelovskoye Lake, 48°25'50.5"N 134°13'28.1"E, oak forest with aspen and birch, on bark of *Populus tremula*, 10.09.2015, I.F. Skirina (VGEO 34370). KHABAROVSK TERRITORY, Komsomolsky District,

Komsomolsky Nature Reserve, the vicinity of the Kamenka Cordon, 50°43'24.5"N 137°25'08.0"E, alt. 317 m, mixed forest, on bark of *Quercus mongolica*, 08.09.2018, S.V. Chesnokov 7 (VBGI 102558); *ibid.*, left bank of Baturin River, 50°47'31.9"N 137°50'02.3"E, alt. 34 m, *Betula* sp.–*Quercus mongolica* forest with *Larix* sp., on bark of *Quercus mongolica*, 15.09.2018, L.A. Konoreva 113 (LE L-27780). PRIMORYE TERRITORY, Dalnerechensky District, near the Orekhovka River, Belokamennoye land type, Izvestkovaya Mt., peak, 45°26'29.7"N 134°34'20.1"E, alt. 278 m, on *Quercus mongolica*, 09.07.2023, F.V. Skirin, det. I.F. Skirina, F.V. Skirin (VGEO 37928); Mikhailovsky District, the vicinity of Ivanovka village, 44°00'21.5"N 132°27'04.5"E, alt. 122 m, *Quercus dentata* forest with *Populus tremula*, on bark of *Quercus dentata*, 15.09.2020, S. V. Chesnokov 1 (VBGI 156521); Khasansky District, Kedrovaya Pad Reserve, surroundings of the station, right bank of the Kedrovaya River, 43°06'02.9"N 131°33'18.4"E, alt. 68 m, small-leaved forest, on bark of *Acer* sp., 03.10.2020, L.A. Konoreva 206 (LE L-27583); Partizansky District, valley of the Kupol spring, watershed between the western and eastern sources, 43°25'33.9"N 133°02'37.6"E, alt. 750 m, *Pinus koraiensis*–broadleaf forest with fir, on a fallen branch, 05.05.2019, F.V. Skirin, det. I.F. Skirina (VGEO 36112); Shkotovsky District, Anisimovka railway station, 43°10'10.6"N 132°46'35.4"E, poplar forest, on bark of *Populus suaveolens*, 1972, L.A. Knyazheva, det. I.F. Skirina (VGEO 32280).

Myelochroa entotheiochroa (Hue) Elix et Hale (Fig. 1C)

This species easily distinguished from other *Myelochroa* species by the presence of reticulated folds on the upper surface that crack along the ridges, flaking upper cortex, and distinct yellow spots on the pith where cortex is missing. A fragile, wrinkled and peeling cortex is also characteristic of the thallus margin of the apothecia. The folds may resemble pustules, making the appearance similar to *M. leucotyliza* and *M. hayachinensis*. However, *M. leucotyliza* has a fairly hard upper cortex that is difficult to destroy, and the pustules are usually clustered and do not form extended folds; while *M. hayachinensis* contains galbinic acid (P+ orange) and has moniliform cells in the medulla. Among the studied *M. entotheiochroa* specimens (about 140), it was most often found on rocky substrates (about 35 % of the specimens studied) than other *Myelochroa* species.

According to literary data (Hale 1976, Kurokawa & Arakawa 1997, Jayalal et al. 2012, Moon et al. 2015), *M. entotheiochroa* has two chemotypes: leucotylic acid (chemotype 1) or leucotylin (chemotype 2). Moreover, chemotype 1 (containing leucotylic acid) was previously described as an independent species of *M. rhytidodes* (Hale) Elix & Hale (Hale 1976), which was later reduced to synonyms of *M. entotheiochroa* by Kurokawa & Arakawa (1997). We did not find any of the chemotypes described in the literature. All samples we studied using HPLC and TLC contained both leucotylin and leucotylic acid in one thallus. Additionally, chloroatranorin, which has not been previously reported in the literature, was detected in all studied samples (Table 1).

Chemistry: atranorin (M), chloroatranorin (m), secalonic acid A (M), zeorin (m), leucotylic acid (m), leucotylin (m).

Distribution in the Russian Far East: In Russia, the species is known only in the south of the Russian Far East: Jewish Autonomous Region, Khabarovsk and Primorye territories, Sakhalin Region (Sakhalin and Shikotan islands) (Fig. 2B).

Selected examined specimens: JEWISH AUTONOMOUS REGION, Obluchensky District, Bastak Nature Reserve, 43 km of the Kukan road, reserve border, 49°04'23.5"N 133°03'35.6"E, coniferous-broadleaf forest, on bark of *Betula costata*, 28.09.2013, I.F. Skirina,

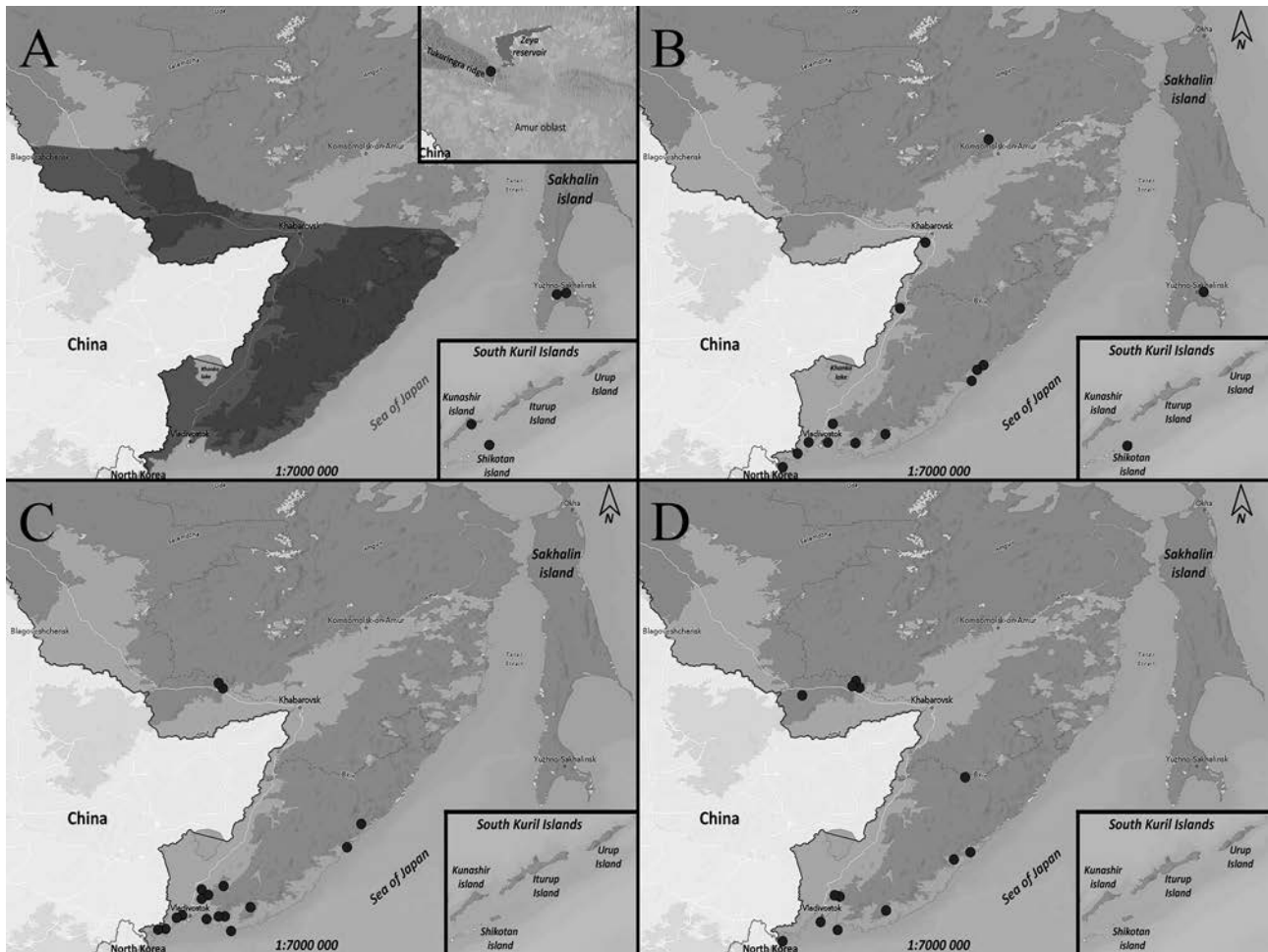


Figure 2 Distribution of *Myelochroa* species on Russian Far East: A – *M. aurulenta* (Tuck.) Elix et Hale, B – *M. entotbeiochroa* (Hue) Elix et Hale, C – *M. galbina* (Ach.) Elix et Hale, D – *M. hayachinensis* (Kurok.) Elix et Hale

det. L.A. Konoreva, S.V. Chesnokov (VGEO 33966); Leninsky District, Daur Ridge, southern territories, 48°04'25.2"N 132°07'26.6"E, oak forest, on oak bark, 18.06.2018, I.F. Skirina (VGEO 35897). KHABAROVSK TERRITORY, Khabarovsk District, Bolshekhkhtsirsky Nature Reserve, Bolshoy Khekhtsyr Mt., 48°13'24.2"N 134°46'45.3"E, alt. 847 m, *Picea* sp.–*Betula ermanii* forest, on bark of *Betula ermanii*, 02.10.2018, S.V. Chesnokov 221 (LE L-27765). PRIMORYE TERRITORY, Shkotovsky District, Litovka Mt., the upper reaches of the Berezovyi spring, 43°06'39.6"N 132°47'21.6"E, fir-spruce forest, on bark of *Betula ermanii*, 28.08.2011, I.F. Skirina, F.V. Skirin, det. I.F. Skirina (VGEO 30196); Khasansky District, Ryzanovka river valley, 42°49'12.8"N 131°13'13.0"E, tall grass with *Angelica* sp., on a rock ledge, 1985, I.F. Skirina (VGEO 6311); ibid., Peter the Great Bay, Marine Reserve, Cape Falshivy Island, 42°27'N 130°47'E, on *Artemisia gmelinii*, 29.05.1987, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 5116); Terneysky District, Dzhigitovka river valley, "Zolotaya Polyana", 44°51'20.8"N 136°04'41.1"E, oak forest with *Pinus koraiensis*, on bark of *Pinus koraiensis*, 1982, I.F. Skirina (VGEO 1044); Ussuriysk District, Ussuri Nature Reserve, Komarovka River, 43°38'50.1"N 132°21'31.7"E, *Pinus koraiensis*–broadleaf valley forest, on bark of *Tilia amurensis*, 08.08.1975, L.A. Knyazheva, det. L.A. Konoreva, S.V. Chesnokov (VGEO 36555). SAKHALIN REGION, Sakhalin Island, vicinity of Yuzhno-Sakhalinsk, Susunaysky Range, Chekhov Peak, "Voronii kamen", 46°59'08.2"N 142°49'43.1"E, alt. 672 m, large boulders in *Betula* sp.–*Sasa kurilensis* forest, on stone, 28.06.2017, L.A. Konoreva 520

(LE L-18398); Yuzhno-Kurilsky District, Shikotan Island, neighborhood of Notoro Mountain, 43°46'50.4"N 146°42'16.9"E, alt. 72 m, *Betula ermanii* forest with *Acer* sp. undergrowth, on bark of *Betula ermanii*, 17.06.2017, L.A. Konoreva 431 (KPABG 20729) and S.V. Chesnokov 203 (LE L-18621).

Myelochroa galbina (Ach.) Elix et Hale (Fig. 1D)

The species belongs to the *M. galbina* group and is characterized by the presence of galbinic acid (P+ orange) and moniliform cells in the medulla, but unlike other species of this group (*M. hayachinensis* and *M. metarevoluta*), *M. galbina* does not form vegetative propagules. Previously all *Myelochroa galbina* specimens studied (about 30) were identified as *M. subaurulenta*. However, despite the morphological similarity, *M. subaurulenta* does not contain galbinic acid (P–), and is characterized by the absence of moniliform cells in the medulla and has wider lobes (in *M. subaurulenta* 5–10 mm, in *M. galbina* 1–3 mm) and smooth upper surface (in *M. galbina* the upper surface is wrinkled).

According to the literature (Hale 1976, Kurokawa & Arakawa 1997, Jayalal et al. 2012, Moon et al. 2015), *Myelochroa galbina* contains atranorin, zeorin, galbinic acid, salazinic acid and secalonic acid A. Hale (1976) and Moon et al. (2015) indicate the presence of leucotylin, whereas in the Japanese material (Kurokawa & Arakawa 1997), most samples contained leucotylic acid. Among the studied samples, we found a chemotype with leucotylic acid. Secalonic acid A were found only a few studied samples. Additionally, chloro-

atranorin and norstictic acid, which has not been previously reported in the literature, was detected in all studied samples (Table 1).

Chemistry: atranorin (M), chloroatranorin (m), norstictic acid (m), galbinic acid (M), salazinic acid (m), zeorin (m), leucotylic acid (m). Some of the *M. galbina* examined samples contained small amounts of the secalonic acid A in the medulla.

Distribution in the Russian Far East: *Myelochroa galbina* was first reported for Russia from Primorye Territory and the Jewish Autonomous Region in the “Lichen Flora of Russia” (Chesnokov & Konoreva 2023), but without locations. Below we list all the studied samples, which became the basis for the “Lichen Flora of Russia”. Additionally, we provide a more detailed distribution map of the species (Fig. 2C).

Selected examined specimens: JEWISH AUTONOMOUS REGION, Birobidzhan District, interfluvium of the 2nd and 3rd Izluchinka Rivers, 48°39'44"N 132°47'06"E, alt. 90 m, *Pinus koraiensis*–broadleaf forest, on bark of *Quercus mongolica*, 17.06.2018, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 35871); *ibid.*, Bastak Nature Reserve, upper reaches of the Ikura River, Ryabinovoy cordon, 48°53'52.0"N 132°52'05.3"E, coniferous-broadleaf forest, on bark of *Abies nephrolepis*, 24.09.2013, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 33622); *ibid.*, floodplain forest with larch, on dry branches of *Picea jezoensis* and *Prunus padus*, 26.09.2013, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 33654); Obluchensky District, 36th km of the road to the Kukan village, 49°02'15.5"N 133°02'15.2"E, alder forest by the road, on bark of *Alnus hirsuta*, 13.08.2002, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 17066); *ibid.*, Krasnye Sopki, 48°58'29.3"N 132°57'09.6"E, oak forest, on bark of *Acer* sp., 27.09.2013, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 33538); *ibid.*, the vicinity of Polkovnikov's apiary in the Kirga River basin, 48°59'13.5"N 132°53'39.8"E, valley forest near the river, on bark of *Prunus padus*, 09.08.2002, I.F. Skirina, V.I. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 15550); *ibid.*, mixed coniferous-broadleaf forest, on bark of *Salix caprea*, *Acer* sp. and *Quercus mongolica*, 07.08.2002, I.F. Skirina, V.I. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 14700); *ibid.*, mixed coniferous-broadleaf forest, near the stream, on bark of *Alnus hirsuta*, 07.08.2002, I.F. Skirina, V.I. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 15321); *ibid.*, behind the oil pipeline, stream valley, 49°03'27.5"N 133°22'20.9"E, deciduous forest, on bark of *Salix* sp. and *Maackia amurensis*, 16.06.2018, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 36013). PRIMORYE TERRITORY, Vladivostok District, Amur Bay, Peschany Peninsula, 43°11'03.4"N 131°44'22.8"E, oak forest, on bark of *Quercus mongolica*, 20.08.1984, I.F. Skirina, N.A. Andrienko, det. L.A. Konoreva, S.V. Chesnokov (VGEO 26889); Nadezhdinsky District, Chertovka River valley, right tributary, upper reaches of the stream, 43°39'42.2"N 132°03'05.6"E, alt. 186 m, gentle slope, oak forest, on bark of *Fraxinus mandshurica*, 05.10.2017, F.V. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 35219); Nakhodka District, the vicinity of Bay of Wrangel, the road to Lake Pervoe, 42°41'49.2"N 133°01'57.2"E, oak forest, on bark of *Quercus mongolica*, 29.06.2012, I.F. Skirina, F.V. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 31808); Partizansky District, Olkhovaya mountain, 43°18'18.6"N 133°39'53.7"E, alt. 540 m, transition from *Pinus koraiensis*–broadleaf to fir-spruce forest, on bark of *Picea jezoensis*, *Abies nephrolepis* and *Acer* sp., 2010, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 29681); Terneysky District, Sikhote-Alin Nature Reserve, Abrek land type, Beya river valley, 45°03'40.6"N 136°41'08.0"E, valley forest, on bark of *Malus baccata* var. *mandshurica*, 10.06.1977, I.F. Skirina, det. L.A. Konoreva,

S.V. Chesnokov (VGEO 35464); Shkotovsky District, Ussuri Nature Reserve, upper reaches of the Koriavaya Pad River, 43°38'53.9"N 132°34'49.6"E, *Pinus koraiensis*–broadleaf valley forest, on bark of *Syringa reticulata* subsp. *amurensis*, 18.07.1975, E.A. Semyonova, det. L.A. Konoreva, S.V. Chesnokov (VGEO 36708); Ussuriysk District, upper reaches of the Bolshaya Kamenka River, 43°41'36.5"N 132°24'53.5"E, *Pinus koraiensis*–broadleaf valley forest, deadwood *Prunus maackii* by the river, 27.07.1975, V.A. Efimova, det. L.A. Konoreva, S.V. Chesnokov (VGEO 29165); *ibid.*, *Pinus koraiensis*–*Picea* sp.–broadleaf valley forest, on bark of *Alnus hirsuta*, 19.08.1975, V.A. Efimova, det. L.A. Konoreva, S.V. Chesnokov (VGEO 33219); *ibid.*, Komarovka River valley, 43°38'03.2"N 132°17'41.9"E, ash forest, on bark of *Quercus mongolica* and *Syringa reticulata* subsp. *amurensis*, 10.10.1958, N. Vokueva, det. L. A. Konoreva, S.V. Chesnokov (VGEO 33325); Khasansky District, Vinogradnaya River valley, 42°46'30.4"N 130°57'01.8"E, alder and willow valley forest, on bark of *Alnus japonica*, 06.09.2008, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 23912); *ibid.*, Kedrovaya Pad Nature Reserve, Kedrovaya River valley, 43°06'27.0"N 131°31'54.6"E, valley forest, on bark of *Juglans mandshurica*, 15.07.1995, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 34551); *ibid.*, valley forest, on bark of *Prunus padus*, 10.07.1999, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 34712); *ibid.*, Ryazanovka River valley, 42°49'39.3"N 131°13'55.9"E, oak forest, on bark of *Quercus mongolica*, 1985, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 6338); Shkotovsky District, beyond the settlement Tikhookeansky towards the settlement Pod'yapolsky, 43°00'04.6"N 132°19'33.6"E, oak forest, on bark of *Quercus mongolica*, 1984, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 30889); *ibid.*, Litovka Mt., upper reaches of the Beryozovyi Stream, 43°07'04.2"N 132°47'37.4"E, fir-spruce forest, on bark of *Abies nephrolepis*, 16.08.1976, L.A. Knyazheva, det. L.A. Konoreva, S.V. Chesnokov (VGEO 31883); *ibid.*, fir-spruce forest, on bark of *Abies nephrolepis*, 29.08.2011, I.F. Skirina, F.V. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 29546); *ibid.*, fir-spruce forest, on bark of *Abies nephrolepis* and *Picea jezoensis*, 1976, L.A. Knyazheva, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 29801); *ibid.*, fir-spruce forest, on bark of *Acer ukurunduense*, 16.08.1967, L.A. Knyazheva, det. L.A. Konoreva, S.V. Chesnokov (VGEO 31882).

***Myelochroa hayachinensis* (Kurok.) Elix et Hale**
(Fig. 1E–G)

The species belongs to the *M. galbina* group and characterized by the presence of pustules and soft and fragile upper surface. Morphologically, *M. hayachinensis* is very similar to *M. leucotylica*, which also forms pustules, but the latter is distinguished by the absence of galbinic acid (P–) and moniliform cells in the medulla, wider lobes (in *M. leucotylica* 2–5 mm; in *M. hayachinensis* 1–3 mm), and a rough upper surface that is not susceptible to destruction (in *M. hayachinensis* the upper surface is fragile (Fig. 1G)). Due to the grouped pustules resembling soralia (Fig. 1F), all studied specimens of *M. hayachinensis* (about 20) were identified as *M. aurulenta*. Due to the fragile upper surface may be confused with *M. entotbeiochroa*. Differences are noted in the species notes *M. aurulenta* and *M. entotbeiochroa*.

The composition of secondary metabolites we identified generally corresponds to literature data (Hale 1976, Kurokawa & Arakawa 1997, Jayalal et al. 2012, Moon et al. 2015). Some authors (Hale 1976, Kurokawa & Arakawa 1997, Moon et al. 2015) also report the content of leucotylin in the medulla. Additionally, secalonic acid A was found in the Korean material (Moon et al. 2015). Among the samples studied, we did not find leucotylin. Secalonic acid A were

found only in a few studied samples. Additionally, chloroatranorin, which has not been previously reported in the literature, was detected in all studied samples (Table 1).

Chemistry: atranorin (M), chloroatranorin (m), galbinic acid (m), salazinic acid (m), zeorin (m). Some of the *M. hayachinensis* examined samples contained small amounts of the secalonic acid A in the medulla.

Distribution in the Russian Far East: *Myelochroa hayachinensis* was first reported for Russia from Primorye Territory and the Jewish Autonomous Region in the “Lichen Flora of Russia” (Chesnokov & Konoreva 2023), but without locations. Below we list all the studied samples, which became the basis for the “Lichen Flora of Russia”. Here *M. hayachinensis* is reported for the first time for the Khabarovsk Territory. Additionally, we provide a more detailed distribution map of the species (Fig. 2D).

Selected examined specimens: JEWISH AUTONOMOUS REGION, Obluchensky District, 40th km of the Kukan road, at the borders of the Bastak Nature Reserve, 49°04'23.5"N 133°03'35.6"E, *Pinus koraiensis*–broadleaf forest, on bark of *Maackia amurensis*, 23.09.2013, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 33994); *ibid.*, upper reaches of the Kirga River, 49°04'59.9"N 132°54'02.1"E, larch peatmoss bog forest and white birch forest, on bark of *Salix caprea*, 15.10.2005, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 31232); *ibid.*, Chernukha Mt., southern slope, 49°05'42.2"N 133°03'23.5"E, fir–spruce forest, on fallen trees of *Abies nephrolepis* and *Betula costata*, 12.08.2002, I.F. Skirina, F.V. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 14411); *ibid.*, the valley of the Kirga River, in the vicinity of Polkovnikov's apiary, 48°59'13.5"N 132°53'39.8"E, *Pinus koraiensis*–broadleaf forest, on bark of *Betula davurica* and *B. fruticosa*, 07.08.2002, I.F. Skirina, V.I. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 15395); *ibid.*, the vicinity of Ovodov's apiary, 500 m north-east of the apiary along the road, 49°07'14.0"N 133°04'07.7"E, coniferous–broadleaf (*Fraxinus* sp., *Alnus* sp.) forest on a swamp, on bark of *Alnus hirsuta*, *Betula costata*, *B. pendula* subsp. *mandshurica* and *Syringa reticulata* subsp. *amurensis*, 12.07.2003, I.F. Skirina, V.I. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 15952); *ibid.*, Malaya Chernukha Mt., 49°07'11.0"N 133°01'36.9"E, coniferous–broadleaf forest, *Tilia amurensis*, 24.09.2013, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 33690); *ibid.*, mountain forestry, vicinity of Bydyr Mt., upper reaches of the Bastak River, 49°11'41.8"N 133°00'37.6"E, fir–spruce forest with *Betula* sp., on bark of *Picea* sp., 17.07.2003, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 15713); *ibid.*, Sutarsky ridge, Pasechnaya cave, 48°55'20.4"N 131°42'0.14"E, alt. 366 m, coniferous–broadleaf forest, on bark of *Pinus koraiensis*, *Acer ukurunduense* and *A. tegmentosum*, 14.06.2018, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 35929); *ibid.*, 48°40'42.6"N 131°37'33.4"E, alt. 239 m, coniferous–broadleaf forests, on bark of *Tilia* sp., *Betula costata*, *Acer ukurunduense*, *A. tegmentosum*, *Phellodendron amurense* and deadwood, 15.06.2018, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 35575). Khabarovsk Territory, Komsomolsky District, Komsomolsky Nature Reserve, the vicinity of the Kamenka Cordon, 50°44'08.7"N 137°23'45.9"E, alt. 228 m, sparse *Quercus mongolica* forest on the top of a hill, with undergrowth of *Populus tremula*, *Betula* sp., *Tilia* sp., on bark of *Quercus mongolica*, 12.09.2018, S.V. Chesnokov 41 (LE L-27781). PRIMORYE TERRITORY, Vladivostok city, Russkiy Island, near the fort No 11, eastern slope of the hill, 42°58'29.1"N 131°53'06.8"E, oak forest, on bark of *Fraxinus chinensis* subsp. *rhynchophylla*, 05.05.2017, E.A. Kuznetsova, F.V. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 36447); Dalnegorsky District, Novitsky Pad', near the combine, hill, slope of western exposure, 44°33'41.0"N 135°39'27.6"E,

oak forest, on fallen trees, 29.07.1980, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 1348); Peter the Great Bay, Askold Island, Cape Palchaty, 42°44'07.4"N 132°21'26.6"E, oak forest, on bark of *Quercus mongolica* and *Carpinus cordata*, 14.10.2017, F.V. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 35107); Lazovsky District, Lysaya Mt. near the village of Benevskoye, Elamovsky spring, 43°14'46.6"N 133°42'57.8"E, *Pinus koraiensis*–broadleaf forest, on bark of *Abies nephrolepis*, 11.09.2013, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 32635); Pozharsky District, valley of the Bikin River, mouth of the Pushnaya River, 46°44'16.7"N 136°01'44.2"E, *Pinus koraiensis*–broadleaf forest, on bark of *Tilia amurensis* and *Alnus hirsuta*, 09.09.1994, S.F. Zholotukhin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 34281); Terneysky District, Dzhitgovka River, right side of the valley, northern slope, 44°50'02.7"N 136°19'56.2"E, oak forest, on bark of *Quercus mongolica*, 24.07.1982, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 1319); Ussuriysk District, Ussuri Nature Reserve, Grabovaya Sopka Mt., northern slope, 43°37'44.4"N 132°21'45.3"E, fir–*Pinus koraiensis*–broadleaf forest, on bark of *Tilia amurensis*, 05.08.1974, E.A. Semenova, det. L.A. Konoreva, S.V. Chesnokov (VGEO 36532); *ibid.*, Bolshaya Kamenka River valley, 43°39'52.0"N 132°23'40.6"E, *Pinus koraiensis*–spruce valley forest, on bark of *Syringa reticulata* subsp. *amurensis*, 1975, E.A. Semenova, det. L.A. Konoreva, S.V. Chesnokov (VGEO 36553).

Myelochroa leucotyliza (Nyl.) Elix et Hale (Fig. 1H, I)

Myelochroa leucotyliza is characterized by the presence of pustules on upper surface and thallus margin of apothecia and a hard upper cortex layer, due to which the pustules retain their shape for a long time and are difficult to destroy. A group of pustules with destroyed apices may resemble soralia, but soredia never form when destroyed. In some cases, individual pustules may resemble developing ridges as in *M. entothelochroa*. Because of this most of the material studied (about 230 specimens) was erroneously identified as *M. aurulenta*, less commonly (about 20 specimens) as *M. entothelochroa*. Morphologically close species is *M. hayachinensis*. For differences from related species, see *M. aurulenta*, *M. entothelochroa* and *M. hayachinensis*.

According to the literature (Hale 1976, Kurokawa & Arakawa 1997, Jayalal et al. 2012, Moon et al. 2015), *M. leucotyliza* is characterized by the presence of atranorin, zeorin, leucotylin and secalonic acid A. Unlike *M. aurulenta* and *M. entothelochroa*, it did not have a chemotype with leucotylic acid. All samples studied contained both leucotylin and leucotylic acid in one thallus. Additionally, chloroatranorin and salazinic acid, which has not been previously reported in the literature, was detected in all studied samples (Table 1).

Chemistry: atranorin (M), chloroatranorin (m), secalonic acid A (M), salazinic acid (m), zeorin (m), leucotylic acid (m), leucotylin (m).

Distribution in the Russian Far East: Previously, the species was considered rare and was known from several habitats on the Kuril Islands (Tchabanenko 2014, Ezhkin 2019). However, a revision of the genus *Myelochroa* showed that *M. leucotyliza* is widespread in the south of the Russian Far East and is common in Jewish Autonomous Region, Khabarovsk and Primorye territories (Fig. 3A).

Selected examined specimens: JEWISH AUTONOMOUS REGION, Obluchensky District, Bastak Nature Reserve, 27th km of the Kukan road, 49°01'26.2"N 133°01'10.7"E, coniferous–broadleaf forest, on bark of *Quercus mongolica*, 27.09.2013, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 33799); *ibid.*, Krasnye sopki, 48°58'29.3"N 132°57'09.6"E, oak forest, on bark of *Phellodendron amurense*, 27.09.2013, I.F. Skirina, det.

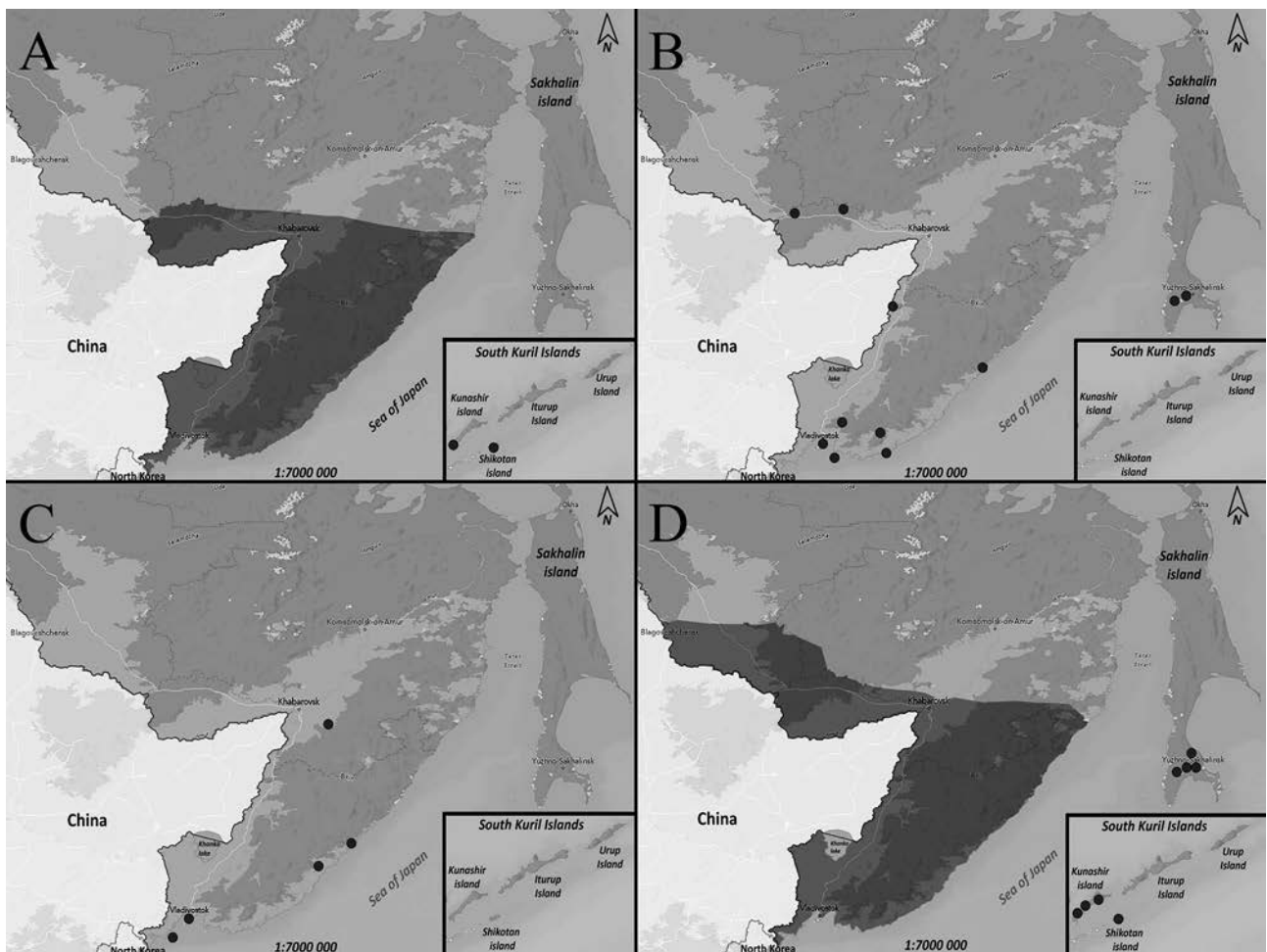


Figure 3 Distribution of *Myelochroa* species on Russian Far East: A – *M. leucotyliža* (Nyl.) Elix et Hale, B – *M. metarevoluta* (Asahina) Elix et Hale, C – *M. perisidians* (Nyl.) Elix et Hale, D – *M. subaurulenta* (Nyl.) Elix et Hale

L.A. Konoreva, S.V. Chesnokov (VGEO 33541). KHA-BAROVSK TERRITORY, Nanaisky District, Khorsky pass, 48°06'25.9"N 136°38'23.0"E, approximately 800 m a.s.l., fir-spruce forest, on bark of *Betula costata*, 1994, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 10157). PRIMORYE TERRITORY, Anuchinsky district, near the Tigrovaya River, vicinities of the Tigrovy village, 43°52'50.8"N 132°48'0.0"E, *Pinus koraiensis* dominated forest, on bark of *Quercus mongolica*, 27.06.2008, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 22472); Dalnegorsky District, left side of Rudnaya River valley, near the Sadovoe village, top of a hill, 44°29'19.3"N 135°43'33.0"E, oak forest, on bark of *Quercus mongolica*, 1980, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 1324); Vladivostok District, Peter the Great Bay, Popov Island, 42°58'04.3"N 131°44'32.3"E, on bark of *Quercus mongolica*, 10.10.1981, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 3630); Mikhailovsky District, vicinity of Gornoye village, Kamchatka Mt., oak forest at the top, 43°59'41.5"N 132°22'50.1"E, alt. 400 m, rocky placers, on stones (phyllites), 19.05.2018, F.V. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 36131); Nadezhdinsky District, railway station Sirenevka, approximately 1 km north of the station, 150 m from the railway line, 43°25'15.6"N, 131°57'10.6"E, oak forest, on bark of *Quercus mongolica*, 29.IV.2006, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 18859); Sovetskii District, Muravyov-Amursky Peninsula, Vladivostok city, 6th kilometer, oak forest, on bark of *Quercus* sp., 24.09.1984, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov

(VGEO 28247). SAKHALIN REGION, Shikotan Island, neighborhood of Tserkovnaya Bay, 43°44'16.5"N 146°41'06.7"E, alt. 30 m, *Picea-Abies* forest, on bark of *Picea* sp., 15.06.2017, S.V. Chesnokov 181 (LE L-18607).

***Myelochroa metarevoluta* (Asahina) Elix et Hale**
(Fig. 4A, B)

The species belongs to the *M. galbina* group and characterized by capitate soralia that form at the ends of the raised lobes, the presence of galbinic acid (P+ orange) and moniliform cells in the medulla. The thallus margin of apothecia is usually covered by a cortical layer, but sometimes slightly sorediose. Most of the studied specimens (a total of about 90 specimens were studied) were presented as associated species. Only 8 specimens were erroneously identified as *M. aurlenta*. *Myelochroa metarevoluta* and *M. aurlenta* are very similar morphologically, but *M. metarevoluta* can be easily distinguished by the presence of galbinic acid (P+ orange) (*M. aurlenta* medulla P–). Additionally, species can be divided by the location of the soralia: in *M. metarevoluta*, soralia are always found at the ends of the lobes (Fig. 2B); in *M. aurlenta*, soralia are often on the upper surface and near the ends of the lobes, but never at the ends.

According to the literature (Hale 1976, Kurokawa & Arakawa 1997, Moon et al. 2015), *M. metarevoluta* is characterized by the presence of atranorin, zeorin, galbinic acid, leucotylin and secalonic acid A. Hale (1976) additionally reported traces of constictic and salazinic acids. Among the samples

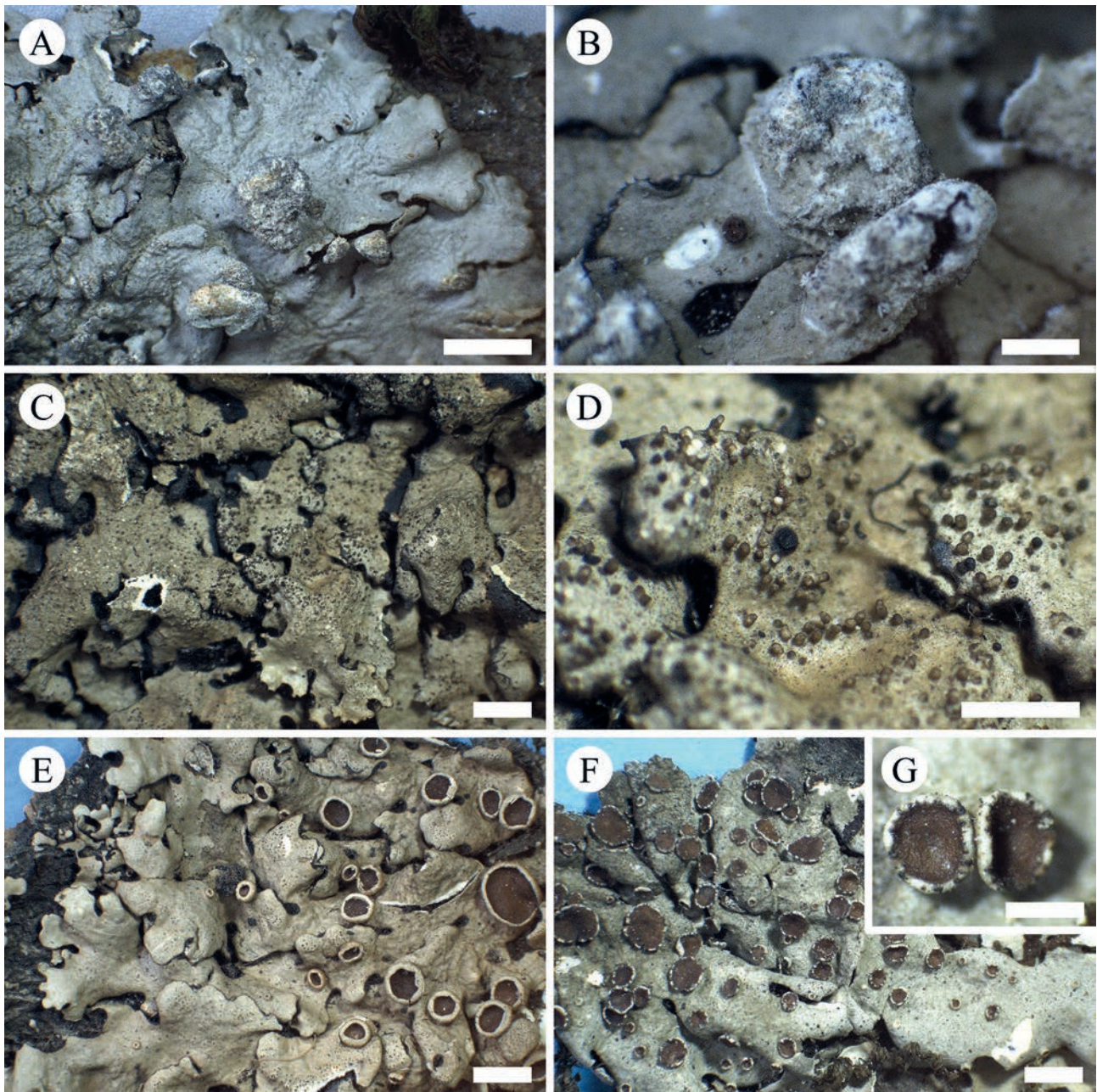


Figure 4 *Myelochroa* species: A – *M. metarevolvata* (Asahina) Elix et Hale, B – capitate soralia of *M. metarevolvata*, C – *M. perisidians* (Nyl.) Elix et Hale, D – isidia of *M. perisidians*, E – *M. subauriculata* (Nyl.) Elix et Hale, F – *Myelochroa* sp., G – pycnidia along the thallus margin of the apothecia of *Myelochroa* sp. Scale bar: A – 3 mm, B, D, G – 1 mm, C, E, F – 2 mm

studied, we find small amounts of secalonic acid A in only a few samples, and instead of leucotylin there is leucotylic acid. All samples contained salazinic acid. Additionally, chloroatranorin and norstictic acid, which has not been previously reported in the literature, was detected in all studied samples.

It is interesting to note that *M. sibirica* and *M. sayanensis*, described from Siberia (Otnyukova et al. 2009), have a similar composition of secondary metabolites with *M. metarevolvata* samples from the south of the Russian Far East. Moreover, both species from Siberia, unlike other *Myelochroa* species, contain secalonic acid W.

Chemistry: atranorin (M), chloroatranorin (m), norstictic acid (m), galbinic acid (m), salazinic acid (m), zeorin (m), leucotylic acid (m). Some of the *M. metarevolvata* examined samples contained small amounts of the secalonic acid A in the medulla.

Distribution in the Russian Far East: The species is widespread in the south of the Russian Far East: Jewish Autonomous Region, Khabarovsk and Primorye territories, Sakhalin Region (Sakhalin Island) (Fig. 3B).

Selected examined specimens: JEWISH AUTONOMOUS REGION, Obluchensky District, Bastak Nature Reserve, the vicinity of Polkovnikov's apiary, 48°58'29.3"N 132°57'09.6"E, larch peatmoss bog forest, on deadwood of *Larix* sp., 09.08.2002, I.F. Skirina, V.I. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 15558); the Malii Khingan ridge, north of the village of Lagar-Aul, 51°49'13.3"N 131°24'0.8"E, alt. 591 m, larch forest on mossy screes, on bark of *Larix* sp., 13.06.2018, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 35723). KHABAROVSK TERRITORY, Komsomolsky District, Komsomolsky Nature Reserve, the vicinity of the Kamenka Cordon, 50°44'08.7"N 137°23'45.9"E, alt. 228 m, sparse *Quercus mongolica* forest

on the top of a hill, with undergrowth of *Populus tremula*, *Betula* sp., *Tilia* sp., on bark of *Quercus mongolica*, 12.09.2018, S.V. Chesnokov 41 (LE L-27722); Khabarovsk District, Bolshekhkhtsirsky Nature Reserve, Bolshoy Khekhtsir Mt., 48°13'24.2"N 134°46'45.3"E, alt. 847 m, *Picea* sp.–*Betula ermanii* forest, on bark of *Acer* sp., 02.10.2018, S.V. Chesnokov 223 (LE L-27760). PRIMORYE TERRITORY, Dalnegorsky District, Sikhote-Alin Nature Reserve, vicinity of the Kabany cordon, Dzhitigovka River, 45°06'33.9"N 135°51'59.4"E, alt. 491 m, *Alnus* forest with *Picea* sp. and *Abies* sp., on bark of *Alnus* sp., 23.09.2020, L.A. Konoreva 143 (VBGI 156589), S.V. Chesnokov 88 (VBGI 156589); Peter the Great Bay, Askold Island, 42°45'13.6"N 132°21'05.0"E, multi-species forest, on bark of *Betula pendula* subsp. *mandshurica*, 14.10.2017, F.V. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 35120); Sovetskii District, Muravyov-Amursky Peninsula, Vladivostok city, Okeanskaya railway station, 43°14'05.6"N 132°00'35.3"E, oak forest, on deadwood, 27.08.1959, L.N. Vasil'eva, det. L.A. Konoreva, S.V. Chesnokov (VGEO 30786); Pozharsky District, spurs of the Strelnikov ridge, 4–5 km from the outpost, 46°37'27.6"N 134°03'05.6"E, oak forest, on bark of *Quercus mongolica*, 20.07.2007, I.F. Skirina, V.I. Skirin, det. L.A. Konoreva, S.V. Chesnokov (VGEO 23023); Terneysky District, mouth of the Serebryanka River, near the village of Terney, 45°02'27.7"N 136°38'57.5"E, *Salix arbutifolia* forest, on bark of *Salix arbutifolia*, *Alnus hirsuta* and *Salix* sp., 17.06.1977, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 35173); Ussuriysk District, Ussuri Nature Reserve, watershed of the Mironov spring, 43°38'52.8"N 132°27'18.1"E, *Pinus koraiensis* forest, on bark of *Pinus koraiensis*, 05.06.1974, L.A. Knyazheva, det. L.A. Konoreva, S.V. Chesnokov (VGEO 33352). SAKHALIN REGION, Sakhalin Island, Yuzhno-Sakhalinsk, Sakhalin Botanical Garden, 46°56'34.4"N 142°46'01.7"E, alt. 90 m, forest near stream with *Betula*, *Alnus* and *Salix* spp., on bark of *Alnus* sp. 07.05.2017, S.V. Chesnokov (SAKH).

Myelochroa perisidians (Nyl.) Elix et Hale (Fig. 4C, D)

Myelochroa perisidians is well distinguished from other *Myelochroa* species by the presence of isidia and yellow medulla. Isidia are also often formed on the thallus margin of apothecia. Morphologically similar species is *M. indica* (Hale) Elix et Hale, which is distinguished by a white medulla (absence of secalonic acid A) and more southern distribution – India (Hale 1976), Nepal (Rai et al. 2017).

The composition of secondary metabolites corresponds to the literature data (Hale 1976, Kurokawa & Arakawa 1997, Jayalal et al. 2012, Moon et al. 2015). Atranorin, zeorin, leucotylen and secalonic acid A were present in all the studied samples. In addition, both leucotylin and leucotylic acid were detected in one sample. The same combination of substances was found in samples from Sri Lanka (Kurokawa & Arakawa 1997). Additionally, chloroatranorin, which has not been previously reported in the literature, was detected in all studied samples (Table 1).

Chemistry: atranorin (M), chloroatranorin (m), secalonic acid A (M), zeorin (m), leucotylin (m), leucotylic acid (m).

Distribution in the Russian Far East: Despite its easy recognition, the species is rare in Russia. Most of the locations of *Myelochroa perisidians* were found in Primorye Territory (22 samples). The species is also known from the Jewish Autonomous Region (Skirina 2015) and Khabarovsk Territory (this paper) (Fig. 3C).

Selected examined specimens: KHABAROVSK TERRITORY, District Imeni Lazo, surroundings of the Mukhen village, upper reaches of Signalny spring, 48°11'15.2"N 136°15'27.9"E, coniferous-broad-leaved forest, on bark of *Tilia amurensis*, 17.07.1983, I.F. Skirina (VGEO 20420). PRIMORYE TERRITORY, Dalnegorsky District, Novitsky

Pad', top of the hill, 44°34'20.4"N 135°39'57.5"E, along the ridge in the eastern and western directions, on bark of *Quercus mongolica*, 1980, I.F. Skirina (VGEO 1596); *ibid.*, ridge between the 4th spring and Novitsky Pad', peak, 44°34'05.6"N 135°40'34.7"E, oak forest, on bark of *Quercus mongolica*, 1980, I.F. Skirina (VGEO 1595); Peter the Great Bay, Bolshoy Pelis Island, northwestern part of the island, 42°39'56.6"N 131°27'23.8"E, on rocks, 1988, L.S. Stepanenko, det. I.F. Skirina (VGEO 6150); Muravyov-Amursky Peninsula, Vladivostok, Ulyss Bay, middle part of the slope, 43°04'54.2"N 131°55'51.1"E, oak forest, on bark of *Tilia amurensis*, 1984, I.F. Skirina (VGEO 30681); *ibid.*, Karier-naya street (6th km), 43°08'59.4"N 131°58'11.6"E, on the bark of *Acer* sp., 28.09.1984, I.F. Skirina (VGEO 27112); Terneysky District, surroundings of the Terney village, "Dubki", oak forest, on bark of *Quercus mongolica*, 26.09.2005, I.F. Skirina, det. I.F. Skirina, F.V. Skirin (VGEO 18174).

Myelochroa subaurulenta (Nyl.) Elix et Hale (Fig. 4E)

Hale (1976), in a monograph of the genus *Parmelia*, recognized the independent species *P. irrugans* (Nyl.) Hale and *P. subaurulenta* (Nyl.) Hale and divided them according to the size of the apothecia (*P. irrugans* – 3–10 mm; *P. subaurulenta* – 1–3 mm). Later, Kurokawa & Arakawa (1997), based on a study of the type specimens of *Parmelia irrugans* Nyl., *P. subaurulenta* Nyl. and *P. subaurulenta* var. *myriocarpa* Asahina concluded that they are ecological forms of the same species. However, their choice of *Myelochroa irrugans* as the adopted name is erroneous. The correct name is *M. subaurulenta*, since its basonym *Parmelia subaurulenta* was published earlier by Nylander (1885) than *P. irrugans* (Nylander 1890).

Myelochroa subaurulenta is characterized by a smooth upper surface of the lobes with many submerged pycnidia, numerous, usually large apothecia (up to 10 mm in diam.) and a yellow or pale-yellow medulla. The species is morphologically similar to *M. galbina* (for differences, see note on *M. galbina*). *Myelochroa subaurulenta* is morphologically very variable, as evidenced by the large number of synonymized taxa (synonyms see under *Parmelia irrugans* and *P. subaurulenta* in Hale (1976)). In total, about 340 samples were studied, among which sometimes there are specimens (about 20) with a large number of small apothecia (up to 3 mm), which corresponds to the description of *Parmelia subaurulenta* var. *myriocarpa* (Asahina 1951). However, a characteristic feature of our samples is the presence of pycnidia along the thallus margin of the apothecia, making the margin appear crenulated, while pycnidia never develop on the upper surface of the lobes (Fig. 4F, G). Unfortunately, there is no information about pycnidia in the protologue and other literature for *Parmelia subaurulenta* var. *myriocarpa*.

Interestingly, there is a difference in the composition of triterpenoids between samples with pycnidia on the thallus margin of apothecia (*Myelochroa* sp.) and the typical *M. subaurulenta*. Thus, samples of *Myelochroa* sp. contain zeorin and leucotylin, while the studied samples of *M. subaurulenta* lack zeorin, but contain leucotylin and leucotylic acid. In general, the composition of secondary metabolites corresponds to literature data (Hale 1976, Kurokawa & Arakawa 1997, Jayalal et al. 2012, Moon et al. 2015). Additionally, chloroatranorin, which has not been previously reported in the literature, was detected in all studied samples (Table 1).

Chemistry: *Myelochroa* sp. – atranorin (M), chloroatranorin (m), secalonic acid A (M), zeorin (m), leucotylin (m); *M. subaurulenta* – atranorin (M), chloroatranorin (m), secalonic acid A (M), leucotylin (m), leucotylic acid (m).

Distribution in the Russian Far East: The species is widespread in the south of the Russian Far East: Jewish

Autonomous Region, Khabarovsk and Primorye territories, Sakhalin Region (Sakhalin, Kunashir and Shikotan islands) (Fig. 3D). The northern boundary of the range apparently runs in the south of Khabarovsk Territory and the southern part of Sakhalin Island.

Selected examined specimens of *M. subaurulenta*:

JEWISH AUTONOMOUS REGION, Obluchensky District, Bastak Nature Reserve, upper reaches of the Kirga River, 49°04'59.9"N 132°54'02.1"E, coniferous-broadleaf forest, on bark of *Tilia amurensis*, *Alnus* sp. and deadwood, 04.10.2005, I.F. Skirina (VGEO 34956); *ibid.*, Dubovaya Sopka Mt., near the cordon, 48°58'54.1"N 132°53'41.7"E, oak forest, on bark of *Quercus mongolica*, 17.10.2005, I.F. Skirina, det. I.F. Skirina, F.V. Skirin (VGEO 18014). Khabarovsk TERRITORY, Khabarovsk District, Bolshekhkhtsirsky Nature Reserve, Bolshoy Khkhtsir Mt., 48°13'28.5"N 134°46'45.1"E, alt. 794 m, *Abies*–*Betula* forest, on branches, 02.10.2018, L.A. Konoreva 393 (LE L-27773, VBGI 102553). PRIMORYE TERRITORY, Peter the Great Bay, Stenin and Ricorda Islands, hornbeam forest, on bark of *Carpinus cordata*, 12.08.1991, L.S. Stepanenko, det. I.F. Skirina (VGEO 37566); Lazovsky District, northern slope of Golaya Mt., local peak at the convergence of ridges, 43°26'59.4"N 133°46'05.9"E, alt. approximately 890–900 m, fir-spruce forest, rock outcrops, on a rock among mosses, 03.05.2021, I.F. Skirina (VGEO 37249); Partizansky District, vicinities of the village of Serebryanoye, middle reaches of the Kupol spring, 43°24'13.3"N 133°03'10.6"E, valley forest, on bark of *Alnus hirsuta*, 04.05.2019, I.F. Skirina (VGEO 36105); Shkotovsky District, Bolshoy Vorobey ridge, northern slope of Tumannaya Mt., 43°14'32.5"N 132°46'50.5"E, alt. 1100 m, fir-spruce forest, on bark of *Abies nephrolepis*, 15.08.2012, F.V. Skirin, I.F. Skirina, det. L.A. Konoreva, S.V. Chesnokov (VGEO 31504). SAKHALIN REGION, Yuzhno-Kurilsky District, Shikotan Island, neighborhood of Malokurilsk village, 43°52'16.1"N 146°50'36.9"E, alt. 96 m, *Abies sachalinensis*–*Taxus cuspidata*–*Betula ermanii* forest with *Acer* sp., on bark of *Abies sachalinensis* and *Acer* sp., 11.06.2017, S.V. Chesnokov 137, 138 (LE L-18571, L-18850); *ibid.*, neighborhood of Notoro Mountain, 43°46'43"N 146°42'16.1"E, alt. 75 m, *Alnus* floodplain forest with *Sorbus* sp. and *Acer* sp., on bark of *Acer* sp., 17.06.2017, L.A. Konoreva 418 (KPABG 20721); *ibid.*, Kunashir Island, Kurilskiy State Nature Reserve, neighborhood of the Rudnyi cordon, right bank of Severyanka River, 44°20'20.9"N 146°00'44.3"E, alt. 12 m, *Ulmus*–*Acer*–tall herb community, on bark of *Acer* sp., 07.06.2019, L. A. Konoreva 71 (VBGI 141455).

DISCUSSION

In total, eight species of *Myelochroa* have been identified for the south of the Russian Far East, six of which form vegetative propagules (soredia, isidia, pustules, fragile surface). These species are characterized by the development of vegetative propagules on the thallus margin of the apothecia. The exception is *M. hayachinensis*, since specimens with apothecia were not found. For the first time, detailed distribution maps of *M. galbina* and *M. hayachinensis* are provided. *Myelochroa hayachinensis* and *M. perisidians* are reported for the first time for the Khabarovsk Territory. The range of *M. leucotylixa*, which was previously considered a rare species in the south of the Russian Far East, has been expanded.

During the study of the secondary metabolite composition of *Myelochroa* species, several new substances were identified (Table 1). Chloroatranorin is reported for the first time for the genus *Myelochroa*. It was found in all samples

studied. Additionally, norstictic acid was found for the first time in *M. galbina* and *M. metarevoluta*, and salazinic acid was reported for the first time for *M. leucotylixa*.

Although literature data indicate that the *M. galbina* group (*M. galbina*, *M. hayachinensis* and *M. metarevoluta*) contains secalonic acid A (Hale 1976, Kurokawa & Arakawa 1997, Jayalal et al. 2012, Moon et al. 2015), we have established that only a portion of the investigated samples contained this compound as a minor constituent.

The presence or absence of leucotylin and leucotylic acid does not appear to be a taxonomically significant feature. Rather, they are related to environmental conditions. This fact was also pointed out by Kurokawa & Arakawa (1997).

Zeorin may apparently have taxonomic significance. For example, its presence or absence allows us to reliably separate *Cladonia coccifera* (L.) Willd. and *C. borealis* S. Stenroos with slight morphological differences (Ahti & Stenroos 2013). In our case, zeorin was found only in *Myelochroa* sp., whereas it was absent in *M. subaurulenta*. Despite the chemical and morphological differences between typical *M. subaurulenta* and *Myelochroa* sp., we will refrain from changing the taxonomic status of the latter for a number of reasons: 1) there is no information in the literature on the presence of pycnidia on the thallus edge of apothecia for *Parmelia subaurulenta* var. *myriocarpa*; 2) there is no possibility to study a typical sample; 3) there is also no information on secondary metabolites for the type specimen, while the literature provides information for *M. subaurulenta* s. lat.; 4) all the studied specimens are too old and are not suitable for DNA extraction.

Key to the species of *Myelochroa* from Russian Far East:

1. Moniliform cells and galbinic acid present (P+ brick red) in the medulla 2
- Moniliform cells and galbinic acid absent (P–) in the medulla 4
2. Soralia or pustules absent; apothecia numerous *M. galbina*
- Soralia or pustules present; apothecia rare or absent 3
3. Pustules absent; capitate soralia present at the ends of raised lobes; upper cortex rough *M. metarevoluta*
- Pustules fragile, often clustered; soredia never formed; the upper cortex fragile *M. hayachinensis*
4. Isidia present *M. perisidians*
- Isidia absent 5
5. Soralia or pustules absent 6
- Soralia or pustules present 8
6. Upper surface strongly wrinkled, often bursting open along the ridges of wrinkles; upper cortex fragile and easily flaking away, exposing yellow medulla ... *M. entotheiochroa*
- Upper surface smooth; upper cortex rough, difficult to destroy 7
7. Pycnidia present on the thallus margin of apothecia; apothecia <3 mm in diam. *Myelochroa* sp.
- Pycnidia absent on the thallus margin of apothecia; apothecia >3 mm in diam. *M. subaurulenta*
8. Upper surface pustular-soredia; soredia are formed from pustules *M. aurulenta*
- Upper surface pustular; soredia never formed from pustules *M. leucotylixa*

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