

## *Euonymus nanus* (Celastraceae) in Europe and in the Caucasus Mountains: geographical distribution, habitats and modern state of populations

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The study of the current state of populations and habitats of rare and threatened species of plants is a relevant task of ecological research. The paper presents the results of investigation of the geographical distribution, habitats and modern state of populations of a rare species of the European and Caucasian floras *Euonymus nanus* M. Bieb. (Celastraceae), included in the Red Data Books of Ukraine, Moldova, the Russian Federation and the Red List of Romania. The structure of the European and Caucasian parts of its range is described. The natural range of *Euonymus nanus* includes Romania (the Carpathian Mountains and the Moldavian Plateau), Moldova (the Moldavian Plateau and Southern Podillia Upland), Ukraine (Podillia and Dnieper Uplands and Dnieper Lowlands, Crimean Mountains) and the Russian Federation (North Caucasus). There are near 100 localities of *E. nanus* in Europe and 6 localities in the Caucasus Mountains. A phytocoenotical peculiarity of European habitats of *E. nanus* is their confinement exclusively to deciduous forests. This is their difference from Caucasian habitats, connected with scree slopes and from Asiatic habitats, connected with coniferous forests. Biogeographical and paleontological data and some biological peculiarities of *E. nanus* (low reproductive potential) confirm its relic nature (Tertiary relic) in Europe. The claim that *E. nanus* has an alien origin in Europe is insufficiently scientifically substantiated. The current state of *E. nanus* populations in Europe and in the Caucasus Mountains is shown. Known local populations of *E. nanus* are few in number, with relatively low densities, and their gradual decline is observed everywhere. Due to the uniqueness of *E. nanus* populations, it must be included to the European Red List. Modelling of *E. nanus* populations in cultivated coenoses is an effective method of *ex situ* conservation for this species.

**Keywords:** biodiversity; community; ecotope; flora; forests; protection; rare species; range; relic; vegetation.

### Introduction

Development of a scientific basis of protection of floristic diversity is a relevant task of ecological surveys. Special attention should be drawn to rare and threatened species of plants of natural floras. Providing protection to them is possible based on integrated studies of geographic distribution, habitats and current state of populations. In the condition of intense anthropogenic pressure on ecosystems, an urgent task, according to the Global Strategy of Plant Conservation (Corlett, 2016), is monitoring the state of populations of rare species represented by low numbers of small populations within their ranges.

Special attention in phytosociological aspect should be paid to the studies of rare and relic species (Primack et al., 2021; Bobo-Pinilla et al., 2022; Holz et al., 2022), in particular, it is important to assess the preservation of rare plants in *ex situ* conditions in botanical gardens (Edwards & Jackson, 2019; Chen & Sun, 2022; Melnyk et al., 2023).

The object of our investigation was a rare relic species of the European flora *Euonymus nanus* M. Bieb. (= *E. nana* M. Bieb.) (Celastraceae), included in the Red Data Books of Ukraine, Moldova, the Russian Federation (Mikheev, 2008; Melnyk & Didukh, 2009; Ghendov, 2015) and in the Red List of Romania (Oltean et al., 1994). Despite its high phytozoological value, this species is not included in the Red List of IUCN, the European Red List and annex to the Bern Convention. Obviously, the reason for this is insufficient knowledge about it. In some in scientific publications erroneous information is given. For example, Ma (2001) cites *E. nanus* for 12 European countries. In fact, it grows in only in four of them.

*Euonymus nanus* is a Euro-Asiatic species. Its disjunctive range consists of the following parts: mountains of Central Asia: Tibet, the Tien-Shan and Alashan (China and Mongolia); in Asia Minor only one locality

in Denezli vilayet, Turkey; Northern Caucasus (Russian Federation); Crimean Mountains (Ukraine); Dnieper and Podolian uplands, Moldavian Plateau, including Suceava Upland and Carpathian Mountains (Ukraine, Moldova, Romania) (Melnyk, 2000).

The Central Asiatic part of *E. nanus* range covers the territories of Causu, Ninghai, Quighai, Shaanxi, Chenxi provinces of China and adjacent territories of Mongolia (Ma, 2001). In the Tien-Shan and Pamir-Alay Mountains in Central Asia the vicarious species *E. koopmannii* Lauche (Leonova, 1974) grows.

The purpose of our research was investigation of geographical distribution, habitats and current state of *E. nanus* populations in the European and Caucasian parts of its range.

### Materials and methods

The investigation is based on materials of field research. During 1986–2023 the monitoring of state of populations was carried out in Ukraine. The geographical distribution of *E. nanus* in the European part of range was established as a result of our field investigations, literary and herbarium data. We studied herbarium specimens stored in: BUCA – herbarium of the Institute of Biology in Bucharest (Bucharest, Romania); CHIS – herbarium of the Chişinău Botanical Garden (Chişinău, Moldova); CL – herbarium of the Alexandru Borza Cluj-Napoca University Botanic Garden (Cluj-Napoca, Romania); KW – herbarium of the M. G. Kholodny Institute of Botany (Kyiv, Ukraine); KWHA – herbarium of the M. M. Gryshko National Botanical Garden (Kyiv, Ukraine); LE – herbarium of the V. L. Komarov Botanical Institute (Saint Petersburg, Russia); MHA – herbarium of the Main Botanical Garden (Moscow, Russia); MW – Moscow University Herbarium (Moscow, Russia);

YALT – herbarium of the Nikita Botanical Garden (Yalta Municipality, Ukraine). Specimens in herbariums that do not have official acronyms in the city of Vinnytsia, Ukraine were also reviewed (places of storage of specimens are listed in the checklist of relevant data).

The distribution map of *E. namus* in Europe and the Caucasus (Fig. 1) was compiled by point method. Habitats and the structure of the *E. namus* populations are studied, according to the methodology described by Rabotnov (1983). Herbarium specimens of *E. namus* from new localities were given to herbarium of the M. M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine (KWAH). Phytocoenological descriptions were conducted according to established methods (Rabotnov, 1983).

## Results

### Checklist of *E. namus* sites in Eastern Europe and the Caucasus

Romania.

Carpathian Mountains.

Bacău County:

Poiana Uzului lake, Sălătruc, Slănic and Colbu (Tomescu & Horeanu, 2009).

Botoșani County:

Baisa (Tomescu & Horeanu, 2009);

Mihăileni (Tomescu & Horeanu, 2009);

Rogojesti – alder-willow grove in a forest, 1928, Topa (CL) (Vojtkó et al., 2017); Rogojesti – Lunca “Racovăț”, 26.07.1948, E. Țopa (CL) (Țopa, 1958); Rogojesti – “Racovăț” meadow, 26.07.1948, E. Țopa (CL); near Rogojesti (in the vicinity of Siret) (CHER) (Chorney, Yakymchuk, 1995);

“Zăiuși” (Tomescu & Horeanu, 2009).

Covasna County:

Bixad – on the riverside Olt near the train station, 1939, M. Godvinschi (Țopa, 1958; Lungu, 1983).

Harghita County:

valley of Csörgő (Giurgău), Bakta and Roman streams, Boros, 1942 (Vojtkó et al., 2017); now in the Gheorgheni river basin (upper reaches of Mureș Basin) and in the Csiki basin along the Olt and its watercourses (Vojtkó et al., 2017);

Remetea village – Roman stream and Bakta stream, 06.08.1942, Boros (Vojtkó et al., 2017); Remetea village – Roman stream, 18.06.1943, Boros (Vojtkó et al., 2017);

Remetea village – Csörgő stream, 06.08.1942 et 18.06.1943, Boros (Vojtkó et al., 2017);

Băile Tușnad – in “Băile cu Stuh” (Țopa, 1958); it is the same, Tușnad – S & SW, resort “Baia de Stuf”, E. Pop, 1954 (Lungu, 1983); it is the same (?) – in “Nadasfürdő”, near Tușnad, E. Pop, 1952 (Vojtkó et al., 2017); ibid maj 2007, S. Lajos, L. Balázs & S.Gábor (Vojtkó et al., 2017);

Borzont village – Fehér stream, 17.06.1943, Boros (Vojtkó et al., 2017); near Corbu village, altitude 1000 m, in a semi-dry shrub (*Rosa gallica* L.), 1 flowering stem, I. Jablonkai, 1955 (Vojtkó et al., 2017) [Note: perhaps the plant appeared here due to zoochoria]; Corbu (“Gyergyoholló”, outskirts of Târgu Ocna in the Bacău region) (Țopa, 1958);

Lăzarea – along the Română stream (Țopa, 1958); Lăzarea, 28.07.1940, E. Țopa (BUCA); com. Lăzarea – Română stream, alt. 720 m, 28.07.1950 (BUCA); Lazărea, “Părăul Română”, alt. 720 m, 17.08.1951, E. Țopa (BUCA, CL); Lazărea, alt. 720 m, 17.08.1951, E. Țopa (CL); Lăzarea – Română stream, a tributary of the Mureș River, alt. 720 m, 17.08.1951, E. Țopa (BUCA);

near Lăzarea – wetlands along the Csörgő stream (tributary of the River Mureș), alt. 719–725 m distr. Ciuc. 15.07.1948, J. E. Nyărădy (CL);

in Vargyas gorge near Merești village (It is located between the counties of Harghita and Covasna), at the bottom of a narrow valley near the Vargyas stream, in a mountain alder grove, on a section of 4 × 10 m, probably appeared due to zoochoria (Vojtkó et al., 2017);

Miercurea Ciuc – W, on the right bank of the Oit River under the forestry school and further along the Cibo stream, more than 50 thousand individuals, 7.06.1956 (Soran et al., 1957);

Subcetate (Țopa, 1958);

Toplița (Tomescu & Horeanu, 2009);

near Voslobeni village – “După Luncă” reserve (Țopa, 1958); near Voslobeni, [“Renul Timor”], 33.06.1967, F. Rot (BUCA).

Neamț County:

Tarcău Mountains, Tarcău valley, 1 km N “Cabana Ardeleuța”, in Abietum, 46.739° N, 26.195° E, alt. 675 m, 21.06.1986, G. Negrean (CL).

Suceava County:

Breaza – on forest limestone and serpentine soil, altitude 800 m, Hormuzaki, 1911 (Vojtkó et al., 2017);

near Breaza – in the valley of the River Moldova (Lungu, 1983);

near Călugăreni – in the Călugăreni Forest (on both sides of the road Suceava – Dorohoi, km 17), 2007 (Tomescu & Horeanu, 2009);

near Fundu Moldovei – mouth of the Lefe stream, Bamarului gorge (Țopa, 1958);

near Moldovița – mountain Dămăcușa (Țopa, 1958) [Note: in the quoted work is written “Moldovița-Ferăstrău” – probably the old name of this village];

along Neagra Broștenilor River, in sandstone, altitude 815 m, 21.08.1965, L. Lungu (BUCA); it's the same, in the valley of Neagra Broștenilor River, from Lunca Borcutului to Cristișor, alt. 815 m (Lungu, 1983);

surroundings of Fălticeni – “Bahna pe dreapta Pir. Racovăț (r. Fălticeni)” (Țopa, 1958);

Zamostea (Țopa, 1958); in the Zamostea-Luncă Reserve (Tomescu & Horeanu, 2009).

Moldavian Plateau (Suceava Upland).

Iași County:

the outskirts of the Grajduri, Bârnova, Mânzătești & Mogoșești villages and along the Stavnic river (Țopa, 1958);

Mircești (Tomescu & Horeanu, 2009).

Vaslui County:

near Bălteni – in a swamp oak forest, 30.05.1925 & 25.06.1929, A. Borza, C. Petrescu & C. Popp (CL); ibid., Petrescu, 1922–23 (Vojtkó et al., 2017); near Bălteni village – in forest, I. Constantineau (Grecescu, 1909) (Țopa, 1958); In the groves near the village Bălteni, on damp, clay soil, 2.08.1964, C. Popp & C. Dobrescu (CL); near Tatomiștești, 1938, P. Enculescu (Lungu, 1983).

Moldova.

Podolian Upland.

Transnistria, Rîbnița District:

near Stroiești – Kalagur forest, 1886 (Montezor, 1888; Shmalgauzen, 1895).

Moldavian Plateau.

Călărași District:

between villages Bahmut and Sipoteni – aspen forest in the valley, 22.06.1957, Lipovaya (CHIS 67090); between villages Bahmut and Sipoteni – in the bushes at the edge of the forest near the railway, 27.07.1960, G. Grosset (MW0432959);

southern outskirts of the Bahmut village – moist oak forest (from *Quercus robur* L.), 27.07.1966, G. G. Postolaki (CHIS67092, 67093, 67094, 67095);

Bahmut – W & E, oak forest in valley, 12.04 & 13.05.1952, L. Nikolaeva, M. Pozharisskaya (Kosykh & Leonova, 1975);

Hîrjauca village – forest on the slopes, 29.08.1951, T. S. Geydeman (MW0432958); hombeam forest on the slopes near Hîrjauca, 29.08.1951, T. S. Geydeman, L. P. & M. P. Pozharisskaya (MW0432960); between villages Hîrjauca & Palanca – hombeam forest on the southwest slope, 22.06.1957, Lipovaya (CHIS67091); ibid. (Geydeman & Nikolaeva, 1961).

Căușeni District:

near Leuntea (Ghendov, 2002).

Dubăsari District:

southern outskirts of the Holercani village (Geydeman et al., 1982; Ghendov, 2002).

Glodeni District:

Moara Domnească (Geydeman et al., 1982).

Hîncești District:

near Lăpușna – quarter 36 of the Kupriyanovsky forest (Geydeman et al., 1982);

Răciula (Simonov, 1961).

Orhei District:

Seliște (Simonov, 1961).

Șoldănești District:

near Olișcani (Geydeman & Nikolaeva, 1961; Simonov, 1961; Geydeman et al., 1982).

Strășeni District:

near Căpriana (Simonov, 1961);

near Onești (Ghendov, 2002);

near Scoreni (Ghendov, 2002).

Ungheni District:

Comești, 1908, Pachosky (MSUD); ibid, 1911, Pachosky (MSUD) (Shmalgauzen, 1895); near Comești – surroundings, in the hornbeam forest, 1.06.1908 (Pachosky, 1912);

Comești – S 3 km of the railway station, in the woods along the thalweg of the valley, 2.05.1911, I. Pachosky (MSUD); it is the same (Pachosky, 1912); Comești – SE, quarters 19, 20, 31 & 33 of the Komesht forest, – and N, quarter 7 of the oak near the railway (Simonov, 1961); near Rădenii Vechi (Ghendov, 2002).

Ukraine.

Carpathian Mountains (Bukovyna).

Chemivtsi region.

Storozhynets district: near Panka – quarter 17 of the Komarivske forestry, oak forest, 03.04.1995, I. Chomey (KW); ibid., Panka – vicinity, age oak forest near the railway station, 03.04.1994, M. Yakymchuk & I. Chomey (KW); it is the same, on the area of 19.8 ha (Chomey & Yakymchuk, 1995).

Podolian Upland.

Khmelnysky region.

Kamianets-Podilskyi district:

vicinity of the Bagowycia village (Gajewski, 1934);

vicinity of the Blishchanivka village (Makovetsky, 1913);

Kyrtaygorod (Gajewski, 1934);

1.5 km from Maliivtsi village (Balkovsky, 1939);

near Mykhailivka (Makovetskiy, 1913);

Zaluchchya – Tsykivska Dacha forest, 31.03.1981, O. Klots (KW); ibid., quarter 17 of the Tsykivska Dacha forest, over the valley of the Smotrych River, on the area of 0.6 ha, 30–35 thousand stems (Kovalchuk & Klots, 1984).

Khmelnysky district:

vicinity of the Krasyliv village (Shmalgauzen, 1895);

S vicinity of the Kryntsiliv, Zlomna tract, in the oak-hornbeam forest, 08.08.1981, O. Klots (KW); ibid., quarter 17 of the Satanivsky forestry (Kovalchuk & Klots, 1984);

1.5 km Lisovody village (Gajewski, 1934);

vicinity of the Oleshyn – on the banks of the Southern Bug River (Rogovich, 1869);

vicinity of the Proskurivka village (Makovetsky, 1913);

vicinity of the Sataniv settlement – in the forest above the Zbruch River, 07.1858, A. Rogovich (KW) (Rogovich, 1869; Shmalgauzen, 1895); ibid., Kryntsiliv – N, Tovtryk tract, in the forest on a slope along the Zbruch River, 22.07.1912 (Pachoskiy, 1915); vicinity of the Kryntsiliv village, 26.07.1935, O. Sokolovsky, V. Shydlovsky (KW); ibid., forest near the Kryntsiliv, on the limestone slopes, 26.07.1935, A. Sokolovsky, V. Shydlovsky (MW0432954).

Odesa region.

Balta district:

the outskirts of the Goldashivka village, in the Kishevo forest, Balkovskiy (KW) (Balkovskiy, 1939);

E vicinity of the Lisnychivka village, Lisnychivsky forest, in the oak from *Quercus petraea* (Kleopov, 1938); ibid., quarter 42 (section 1) of the Lisnychivske forestry, in the oak from *Q. petraea*, 14.08.2013, P. Ustylenko & D. Dubyna (KW 00109865); ibid., "Lisnychivka" Reserve,

48.010556° N, 29.523333° E, 2 loci in quarters 32, & 42 (Ustylenko & Dubyna, 2014).

Temopil region.

Chortkiv district:

vicinity of the Kozyna village, in the Shum tract and Kozyna tract (Oliyar, 2008);

NW vicinity of the Krutyliv village, in the forest above the Zbruch River, 30.05.1913, W. Szafer (Szafer, 1914); ibid., quarter 38 of the Krasnyansky forestry (Oliyar, 2008).

Vinnytsia region.

Bershad district:

vicinity of Bershad town, in the Southern Bug River valley (Andrzej-jovsky, 1861; Rogovich, 1869; Shmalgauzen, 1895);

vicinity of Bershad – along the Dokhna River (a tributary of the Southern Bug), date not specified, Schmalhausen (KW);

vicinity of the Potashnya – quarter 55 of the Bershad forestry, "Ustyanska Dacha" reserve, 27.08.1981, Yavorska (herbarium of the Vinnytsia Local Lore Museum); ibid, in oak forest, 48.3191° N, 29.6423° E, 24.07.2009, O. Shynder.

Chemivtsi district:

N vicinity of Vyla Yaruhski village, on the left bank of the Murafa, in the floodplain hornbeam forest, 48.4659° N, 28.0523° E, 09.04.2009, O. Shynder (KWHHA).

Chechelnyk district:

vicinity of Brytavka village, quarter 53 of the Brytavske forestry, in oak-hornbeam forest, 10.08.1988, T. Andriyenko & O. Pryadko (KW 016207, 016208); ibid., quarters 53, 54, 56, 57, 39, 41, 42, 67, 76, 77, 80, 85 and 88 of the Brytavske forestry (Andriyenko et al., 1997); ibid., quarters 56, 15.07.1990, O. Yavorska (herbarium of the Vinnytsia Local Lore Museum); ibid., quarter 81 (48.152967° N, 29.190767° E, – 19.07.2017), quarter 85 (48.153083° N, 29.173767° E, – 21.07.2017), quarter 87 (48.152533° N, 29.18915° E, – 24.05.2017), quarter 89 (48.152917° N, 29.190983° E, – 25.05.2017) and quarter 106 (48.176167° N, 29.28635° E, – 25.05.2017), scattered, L. Markivska (Markivska, 2020);

W vicinity of the Brytavka, Luzhske forestry, quarter 5 (48.218479° N, 29.107849° E, 22.07.2020); ibid., quarter 26 (48.190533° N, 29.126553° E, 02.06.2017); ibid., the boundary between quarter 38 & 39 (48.18725° N, 29.1067° E, 31.05.2017); ibid., quarter 39 (48.18735° N, 29.106833° E, 48.187167° N, 29.10408° E & 48.18595° N, 29.106833° E, – 31.05.2017); ibid., quarter 54 (48.182579° N, 29.131676° E & 48.182964° N, 29.131689° E, – 23.07.2020); ibid., quarter 55 (48.184261° N, 29.132479° E, 48.183495° N, 29.132936° E & 48.182434° N, 29.132338° E, – 23.07.2020) (Markivska, 2020);

SW vicinity of Stratiyivka village, Lubomyrske (another name – Stratiyivske) forestry, quarter 72 (48.124916° N, 29.375317° E, 48.125523° N, 29.375099° E & 48.124527° N, 29.375486° E), 22.05.2020, Markivska (Markivska, 2020);

S vicinity of the Popova Hreblyia village, quarter 46 of "Chervonogreblyansky" reserve, oak grove (Markivska, 2014).

Haisyn district:

vicinity of Harpachka village, in moist shaded sites, sub *E. marschallianus* (Andrzejowsky, 1823; Rogovich, 1869).

Mohyliv-Podilskyi district:

Bandyshivka – N, on the right bank of the Murafa River (opposite Bukatynka village), in the forest, 01.08.2005, M. Fedoronchuk (KW 097943);

vicinity of Lomaziv village, in the forest, 07.1936, F. Shchepotiev (KW);

Hrabarivka (formerly name Izrailivka), 3.06.1928, Yankovsky (herbarium of the Vinnytsia State Pedagogical University).

Murovani Kurylivtsi district:

vicinity of the Vinozh, in the forest (Balkovskiy, 1939);

vicinity of Kotyuzhany village, quarter 64 of Kotyuzhansky forest, 2 local populations at a distance of 2–3 km from each other (the larger population has an area of about 4 hectares) (Shchepotiev, 1938);

vicinity of Nemerche village, in the hombeam-oak forest, large thickets, 12.08.1927, Y. Kleopov (KW);

vicinity of Nemerche, over the Bigucha River, 03.06.1928, K. Yan-kovskiy (KW); *ibid.*, on the slope of the Bigucha River (a tributary of the Lyadova River), 03.06.1928, M. Bilozir (KW); *ibid.*, on the slope of the Bigucha River, 03.06.1928, M. Bilozir (MW0432953, 0432956); near Nemerche village, in the forest, on the Ludava River banks, 2 large mats, 12.08.1927 (Kleopov, 1928; Kleopov & Hryn, 1933).

Nemyriv district:

Hrynenky – E, Hrynenkivsky forest, 26.07.1937, F. Hryn (KW);

vicinity of the Oleksiivka, in the valley of the Southern Bug River, 08.1932, F. Hryn (KW); Oleksiivka – E (in the direction of the Sokiltsi), Dubina forest, sand terrace of the Southern Bug River, 11.09.1932 (Hryn & Mykhaylychenko, 1933; Kleopov & Hryn, 1933);

Sytkivtsi – E, quarter 47 of the Sytkivtsi forestry, 07.1936, F. Shchepotev (KW); *ibid.*, quarters 47 & 48, 23.06.1932, F. Hryn, V. Mykhaylychenko (KW); it is the same (Hryn & Mykhaylychenko, 1933; Kleopov & Hryn, 1933);

vicinity of the Sorokotyazhyntsi, in Krykivetska Dacha forest, 11.08.1932, F. Hryn (KW); it is the same, Nemyrivske forestry, quarters 92 & 93, slope in the in the hombeam forest (Hryn & Mykhaylychenko, 1933; Kleopov & Hryn, 1933);

vicinity of the Verkhnya Kropyvna, quarters 8–10 of Sitkivtsi forestry, 25.07.1932, Hryn & Mykhaylychenko (KW); it is the same (Hryn & Mykhaylychenko, 1933; Kleopov & Hryn, 1933);

Vyshkivtsi – N, Yukhnokove tract, in a hombeam grove on the slope above the Shpykivka River, 10.1935, B. Balkovskiy (KW) (Balkovskiy, 1939).

Trostanets district:

near Berezhanka – quarter 45 of Tsybulivske forestry, "Haydamatska Balka" Reserve (Didukh & Vashenyak, 2010);

between Ladyzhyn and Hlybochok – in the alder thickets of the Southern Bug valley (Andrzhajevskiy, 1861; Rogovich, 1869) [Note: this location was later indicated as two different habitats – Hlybochok and Ladyzhyn (Kotov, 1955)];

Obodivka – SE, Obodivske forestry, in the oak-hombeam forest, 20.06.1969, D. Ivashyn, I. Moroz, N. Antonyuk & B. Sydoruk (KWWA); *ibid.*, Obodivska Dacha forest (Didukh & Vashenyak, 2010);

Obodivka – S, Tsybulivske forestry, 08.08.2006, H. Choma & M. Fedoronchuk (KW 067547).

Tulchyn district:

Pechera village – in the woods along a stream on a slope in the Southern Bug River valley (Balkovskiy, 1939).

Tyvriv district:

near Tyvriv (Orlov, 1985, map 17).

Zhmerynka district:

Zhmerynka – E, Lelyako-Mohylivska Dacha forest (Orlov, 1985: map 17).

Prut-Dniester Interfluve.

Chemivtsi region.

Sokyryany district:

Kobolchyn – vicinity, Djurdzhova tract, 20.06.1994, leg. L. Kuchinik, det. I. Chomey (KW);

near Kobolchyn – Kobolchyn ravine (Volutsa, 2007).

Dnieper Upland.

Cherkasy region.

Chyhyryn district: Matviyivka – E, Matviyivsky Forest, Vovchy Shpyl hill, 29.06.1937, F. Hryn (KW); *ibid.* (Kleopov, 1938); *ibid.*, quarter 55 of the Matviyivske forestry, 08.06.1978, V. Kurson (KW); *ibid.*, quarter 52 (Kurson, 1978) [Note: the indication from the article probably refers to the same location where the herbarium sample was taken, so only one of the two numbers of forestial quarters is correct and the other is false];

Ivanivka (former name – "Yanych") – Yanichanske forestry, hombeam-oak forest, 01.09.1937, Y. Kleopov & F. Hryn (KW) (Kleopov, 1938);

Melnyky – W, Kholodnyi Yar forest, quarter 55 of the Kresetske forestry, 08.06.1978, V. Kurson (KW); it is the same, on the area of 2 hectares (Kurson, 1978; Shelyah-Sosonko & Kurson, 1979); *ibid.*, quarter 59 of the Kresetske forestry, in the gully, small (Shelyah-Sosonko, Kurson, 1979); *ibid.*, 49,156025° N, 32,270122° E, 2010–2018, V. Konogray & O. Spryagaylo (Vasylyuk et al., 2019);

Zamyatnytsia – SW, Kholodnyi Yar forest, quarter 2 of the Kresetske forestry, 10.10.1983, A. Temchenko (KW); *ibid.*, on areas of several tens of square meters, 49.184132° N, 32.282547° E, 2002 (Shevchyk, 2019); *ibid.*, 49,184392° N, 32,282748° E, 2018, O. Spryagaylo & O. Spryagaylo (Vasylyuk et al., 2019).

Smila district: between the villages Pastyrskye and Kapitanivka, in hombeam forest, in the north-east parts of the Kapitanivske forestry, on the slopes of a moist forest gully, in a young hombeam forest, 2005 (Shevchyk et al., 2009; Shevchyk, 2019); *ibid.* (western outskirts of the Pastyrskye village), in Tsyhanskyi Yar gully, 18 quarter of the Kapitanivske forestry and 69 quarter of the Makiivske forestry, hombeam forest, 9.11.2021, Melnyk, Shnyder & Didenko (KWWA);

Buda-Makiivka village – E, near Ivankovyi stav, quarters 24 & 31 of the Makiivske forestry, slopes in hombeam forest, 9.11.2021, Melnyk, Shnyder & Didenko (KWWA);

Buda-Makiivka village – E, in Sotnytskij Yar gully, 9.11.2021, Melnyk, Shnyder & Didenko (KWWA).

Uman district: Uman – E, Bilogrudivsky forest, 15.05.1941, N. Onyshchenko & F. Hryn (KW); *ibid.*, up to 2.2 hectares (Onyshchenko, 1947); *ibid.*, in hombeam-oak grove, site area 3652 m<sup>2</sup> (Butylo, 1992); *ibid.*, the slope of the forest gully, 2 loci (1.1 and 1.6 ares), 05.09.1983, I. Udra & M. Romanenko (KW); near Yatranivka (Choma et al., 2009).

Kirovohrad region.

Oleksandrivka district: Chuta forest (northern part), quarter 29 (now – Dmytrivske forestry), along the thalweg of the gully Kishla, near the forester's house, 1910, G. Vysotsky (Pachoskiy, 1915); *ibid.*, 16.06.1913, I. Pachoskiy (Pachoskiy, 1915).

Znamyanka district: Dmytrivka – NW, Chuta forest, Dmytrivske forestry, 24.07.1976, V. Kurson (KW); *ibid.*, quarters 6 & 20 of the Dmytrivske forestry (Kurson, 1978);

Chomyi Lis forest, 06.1937, F. Hryn (KW); *ibid.*, 18.05.1949, F. Hryn (KW); *ibid.*, 06.1978, V. Kurson (KW); *ibid.*, quarters 87 & 88 of the Bogdanivske forestry (former name – Khyrivske forestry) (Kurson, 1978) [Note: now presumably disappeared due to the construction of a military base]; Vodyana village – NW 4–5 km, Chomyi Lis forest, at the bottom of the gully, 9.09.1956, G. Grosset (MW0432949, 0432950, 0432951, 0432952); Chomyi Forest – Bogdanivske forestry, on the thalweg of the Chomoliska gully (Svystun, 2001).

Dnieper Lowland.

Kyiv region.

Pereyaslav district: vicinity of Kovalyn village, Stovpjagske forestry (19 quarter). Deciduous forest, 7.07.2023, Melnyk (KWWA).

Crimean Mountains.

Autonomous Republic of Crimea.

Simferopol district: Subatkan-Yayla (Dovgorukivska yayla), in the valley of the Burulcha River, the edge of a hombeam-beech forest, in a cleft of a limestone block, 8.08.1974, V. Kosykh (Kosykh & Leonova, 1975); *ibid.*, 09.08.1974, Kosykh (YALT) – 28.08.1975, Kryukova (YALT) – 30.08.1986, Golubev (YALT) – 12.06.2012, Isikov (YALT) (Isikov & Astafeva, 2019); *ibid.*, along the Burulcha River, at the site of 100 × 2–10 m, a total of about 700 stems (Isikov & Astafeva, 2019); Dovgorukivska yayla, Burulcha River valley, [44,7798° N, 34,2854° E], 15.07.1980, T. Vylegzhaniina (MW 0618430);

Chatyr-Dag – on the Middle plateau, in the middle between Angar-Burun and Eklizi-Burun (Golubev, 1991); *ibid.*, 19.09.1990, Golubev (YALT); 24.09.1990, Golubev (YALT) (Isikov & Astafeva, 2019); Chatyr-Dag – the middle plateau, near the Partyzanska cave, grows in three places, 44.767° N, 34.283° E, in the largest locus more than 700 stems (Isikov & Astafeva, 2019);

Grand Canyon – right wall at the top of the Canyon, 44.527909° N, 34.015032° E, 12.08.2020, D. Epikhin (Ueda, 2021).

Russian Federation.  
Caucasus Mountains.  
Kabardino-Balkaria.

Chegemsky District: Chegem gorge, above Bulungu village, on the slopes of Chodurgu, altitude 1700 m, 25.05.1987, S. Shkhagapsoev (LE); Chegem river gorge, above Bulungu, on the slopes of Chodurgu, 07.05.1989, S. Shkhagapsoev (MW0691414); Chegem River gorge (left side), above Bulungu, scree, southern slope, alt. 1650 m, 25.05.1987, S. Shkhagapsoev (LE); in the Chegem gorge, 1.5 km above Bulung, total 69 individuals (Shkhagapsoev, 1989); Chegem river gorge, on the slope of Mount Hinckley, 26.06.1994, N. Starikova & S. Shkhagapsoev (LE).

Chereksky District: near Bezengi village – in the Cherek Bezengiy-sky gorge (Mikheev, 2008; Portenier, 2012).

Karachay-Cherkessia.

Karachayevsky District: The origins of the Kuban River, on the rocks between the bushes near Hurzuk aul, rarely, alt. 2480 m, 30.06.1900, N. Desulavi (LE) [Note: the location discovered by N. Desulavi was erroneously assigned to the territory of Georgia (Kosykh, Leonova, 1975)];

Teberda Nature Reserve – mountain range Great Hatipara, in the basin of the Teberda River, between the mouths of its tributaries – Hajibey and Great Hatipara (Zemov, 2013).

Stavropol Krai.

Kavkazskie Mineralnye Vody area:

Pyatigorsk – "circa thermas Constantinomontanas in saxosis", Steven (Bieberstein, 1819); it is the same (Kosykh & Leonova, 1975); Pyatigorsk –

Mount Beshtau, Steven (locus classicus) (Galushko, 1967; Kosykh & Leonova, 1975); *ibid.* (Grossgeym, 1962);

Pyatigorsk – Gora Goryachaya (Ivanov, 2002);

Zheleznovodsk – N, the top of the western slope of Gora Razvalka, near the outlets of cold air from fissures, 23.07.1992, G. Konechnaya & A. Khaare (LE); Mt. Razvalka, Zheleznovodsk 44.159833° N, 43.034833° E, alt. 640 m (Cubey, 2018).

*Habitats.* During our field investigation in the south of the Podolian Upland we found a new habitat of *E. nanus* in durmast oak forest *Quercetum (petraea) caricosum (brevicollis)* (Fig. 2). This forest massif is situated among the villages Brytavka Chechelnyk district, Vinnytsya region and Ivashkove Kodyma district, Odesa region on the territory of the National Nature Park "Karmelyukove Podillya" (32 quarter of Brytavka forestry). The first layer of the tree stand is formed by centenary *Quercus petraea* (Matt.) Liebl. Some oak trees are even older: more than 250 years old. Single trees of *Acer campestre* L., *Fraxinus excelsior* L. and *Tilia cordata* Mill. are members of this layer. The second tree layer is formed by *Carpinus betulus* L. with participation of rare species of Ukrainian flora *Sorbus torminalis* (L.) Crantz.

The shrub layer is formed by *Crataegus monogyna* Jacq. and *Euonymus europaeus* L. The forest floor flora is represented by *Carex brevicollis* DC. together with *Aegopodium podagraria* L., *Asarum europaeum* L., *Cruciata glabra* (L.) Opiz and rare endangered species included in the Red Book of Ukraine: *E. nanus*, *Epipactis atrorubens* (Hoffm.) Besser, *Lilium martagon* L., *Platanthera bifolia* (L.) Rich., *Scopolia carniolica* Jacq. and rare species for the Podolian Upland *Arum besserianum* Schott and *Hedera helix* L. Density of the population of *E. nanus* is 1–5 vegetative shoots per 1 km<sup>2</sup>.

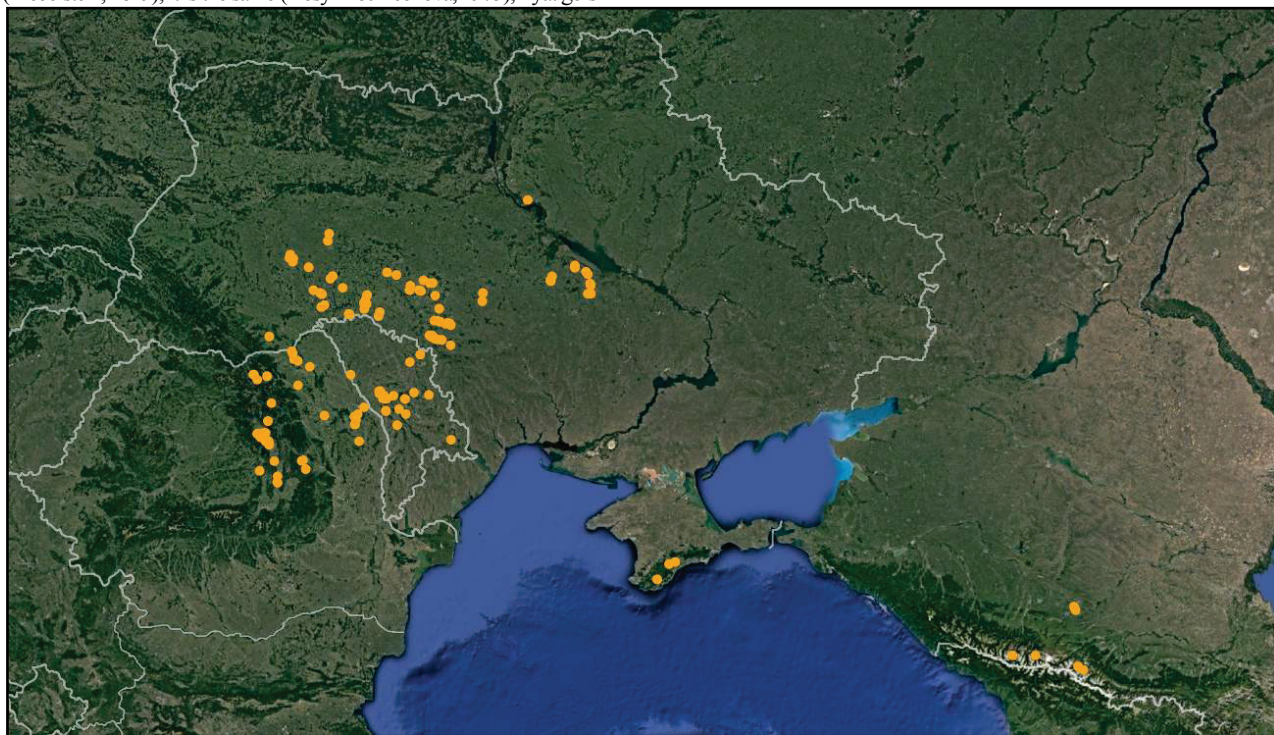


Fig. 1. Distribution of *Euonymus nanus* in Eastern Europe and the Caucasus

In the Podolian Upland *E. nanus* grows also in floodplain forests. We described the habitat in the floodplain hombeam forest with *E. nanus* near Vyla Yaruhski village, Chernivtsi district, Vinnytsya region. This habitat is located on the left bank of the Murafa River. The tree layer is formed by *Carpinus betulus* (60–80 years old) with the participation of *Acer campestre*, *Fraxinus excelsior*, *Prunus avium* (L.) L., *Ulmus laevis* Pall. Single *Corylus avellana* L., *Euonymus europaeus*, *Sambucus nigra* L. and *Viburnum opulus* L. form the sparse shrub layer. The forest floor plants are represented by *Equisetum hyemale* L., *Euonymus nanus*, *Pulmonaria obscura* Dumort., *Isopyrum thalictroides* L., *Aegopodium podagraria*, *Asarum europaeum*, *Melica picta* K. Koch, *Brachypodium*

*sylvaticum* (Huds.) P. Beauv., *Geum urbanum* L., *Lamium galeobdolon* (L.) L. In the spring there is a rich cover of ephemeroïds: *Anemone ranunculoides* L., *Corydalis cava* (L.) Schweigg. & Körte, *C. solida* (L.) Clairv., *Gagea lutea* (L.) Ker Gawl., *Galanthus nivalis* L. and *Isopyrum thalictroides*. The population of *E. nanus* occupied a small space and consisted of 300 vegetative shoots.

Our detailed phytocoenotical investigation *E. nanus* on the Dnieper Upland have shown the specificity of its habitats (Fig. 3). In Makiivske forestry in Cherkasy region, it grows mainly in hombeam and in hombeam-oak forests. In the 24 and 31 quarters of Makiivske and in Kapitanivske forestries it is connected with hombeam forest *Euonymo-nanae* – *Carpi-*

netum association. The tree layer is formed by 50 year old trees of *Carpinus betulus* with participation of *Acer campestre*, *A. platanoides* L., *A. tataricum* L., *Betula pendula* Roth, *Fraxinus excelsior*, *Populus tremula* L., *Prunus avium*, *Quercus robur*, *Tilia cordata*, *Ulmus laevis*. Young growth is represented by *Carpinus betulus*. The sparse shrub layer is formed by *Corylus avellana*, *Euonymus europaeus*, *E. verrucosus* Scop., *Sambucus nigra*, *Viburnum lantana* L. The small shrub-grass stand is sparse (50%) and represented by *Euonymus nanus* (20%), *Aegopodium*

*podagraria*, *Asarum europaeum*, *Carex pilosa* Scop., *Epipactis helleborine* (L.) Crantz, *Lamium galeobdolon*, *Poa nemoralis* L., *Pulmonaria obscura*, *Stellaria holostea* L. This hombeam forest is derivate of hombeam-oak forest, which forms as a result of oak tree felling. In some places of this forest massif there are relicts of the primary hombeam-oak forest. The local population of *E. nanus* occupied an area of 23.9 ha, it density was 50 shoots per 1 m<sup>2</sup>.



Fig. 2. *Euonymus nanus* in Karmelukove Podilla National Nature Park (Vinnytsia region)



Fig. 3. Population of *Euonymus nanus* in Makiivske forestry (Cherkasy region)

Similar habitat is in 69 quarter of Makiivske forestry and in 18 quarter of Kapitanivske forestry. Here *E. nanus* is connected with hornbeam forest *Carpinetum caricosum (pilosae)* association. This habitat is situated in Tsyhanskyi Yar gully.

The tree layer is formed by *Carpinus betulus* with participation of *Acer platanoides*, *Fraxinus excelsior*, *Populus tremula*, *Prunus avium*, *Quercus robur*, *Tilia cordata*, *Ulmus laevis*. Young growth is represented by *Carpinus betulus*. The sparse shrub layer is formed by *Corylus avellana*, *Euonymus verrucosus*, *Sambucus nigra*, *Viburnum lantana*. The small shrub-grass stand is sparse (60%) and represented by *Carex pilosa* (dominant, 25%), *Aegopodium podagraria*, *Asarum europaeum*, *Lamium galeobdolon*, *Glechoma hederacea* L., *Epipactis helleborine*, *Mercurialis perennis* L., *Pulmonaria obscura*, *Stellaria holostea*, *Viola canina* L., *V. suavis* M. Bieb. and *E. nanus*.

The population of *E. nanus* is situated at the bottom of a gully and stretches along the forest stream. Its projective cover is 5–10%. Here, population of *E. nanus* occupied 42.8 ha. The average population density is 50 vegetative shoots per 1 m<sup>2</sup>, maximum population density is 120 vegetative shoots per 1 m<sup>2</sup>.

In Sotnykij Yar gully (27 and 30 quarters of Makiivske forestry) *E. nanus* grows in hornbeam-oak forest *Carpineto (betulis) – Quercetum stellariosum (holostea)*. The first layer is formed by 100-year old *Quercus robur* and second layer is formed by the younger 60-year old *Carpinus betulus*. Single trees of *Acer platanoides*, *Fraxinus excelsior*, *Populus tremula*, *Prunus avium*, *Tilia cordata*, *Ulmus laevis* are components of the timber stand. Young growth is represented by *Carpinus betulus*. The sparse shrub layer is formed by *Corylus avellana*, *Euonymus verrucosus*, *Sam-*

*bucus nigra* and *Viburnum lantana*. The small shrub-grass layer (projective cover is 60%), is composed of *Aegopodium podagraria*, *Asarum europaeum*, *Carex pilosa*, *Lamium galeobdolon*, *Glechoma hederacea*, *Epipactis helleborine*, *Mercurialis perennis*, *Pulmonaria obscura*, *Vinca minor* L., *Viola canina*, *V. suavis* and *E. nanus*. The population of *E. nanus* is situated at the bottom of a gully and stretches along the forest stream. Its projective cover is 10–15%. Twenty years ago, part of this timber stand was felled (as evidenced by big old stumps) and was replaced by dense thickets of coppice *Ulmus laevis*, *Populus alba* L., *P. tremula*. The small shrub-grass layer is not formed and represented by single plants, listed above and small thickets of *Equisetum hyemale* L. Projective cover of *E. nanus* is no more than 1%. Substitution of primary hornbeam forest by thickets (as result of felling) negatively affects the habitats of *E. nanus*. Here the population of *E. nanus* occupied 28.8 ha. Average population density is 30 vegetative shoots per 1 m<sup>2</sup>, maximum population density 70 vegetative shoots per 1 m<sup>2</sup>.

In Zubovskij reserve (Kreslecke forestry, 2 quarter) in Cherkasy region *E. nanus* grows in hornbeam forest on the slope of the gully (Fig. 4). The tree layer is formed by 60 year old trees of *Carpinus betulus* with participation of *Acer platanoides*, *Fraxinus excelsior*, *Populus tremula*, *Tilia cordata*, *Ulmus laevis*. A sparse shrub layer is formed by *Corylus avellana*, *Euonymus verrucosa*. The herb layer is composed of *Aegopodium podagraria*, *Asarum europaeum*, *Carex pilosa*, *Stellaria holostea*, *Pulmonaria angustifolia* L., *Corydalis solida*, *Scilla bifolia* L. The area of the reserve is 0.2 ha. The local population of *E. nanus* occupied a plot of 150 × 20 m. The density of this population is 5 shoots per 1 m<sup>2</sup>.



Fig. 4. *Euonymus nanus* in Kreslecke forestry (Cherkasy region)

In its single habitat in the Dnieper Lowland in Stovpjagske forestry *E. nanus* is confined to oak forest *Quercetum (roboris) corylosum (avellanae)* on an area of 3.3 ha. The dominant of tree layer is *Quercus robur*, the components are *Acer campestre*, *A. platanoides*, *Fraxinus excelsior*, *Populus tremula*, *Ulmus laevis*. The shrub layer composed from *Corylus avellana*, *Crataegus monogyna*, *Euonymus verrucosa*, *Frangula alnus* Mill., *Viburnum opulus*.

The herb layer is sparse. It consists of *Actaea spicata* L., *Aegopodium podagraria*, *Asarum europaeum*, *Convallaria majalis* L., *Campanula rapunculoides* L., *Glechoma hederacea*, *Lamium galeobdolon*, *Luzula pilosa* (L.) Willd., *Mercurialis perennis*, *Polygonatum latifolium* (Jacq.) Desf., *P. multiflorum* (L.) All., *Viola hirta* L., *V. odorata* L. and rare species of plants included in the Red Book of Ukraine *Epipactis helleborine*, *Lilium*

*martagon*, *Platanthera bifolia*. The small local population of *E. nanus* consists of 40 individuals. The density of population is 1 individuals per 1 m<sup>2</sup>.

## Discussion

Question of the origin of *E. nanus* in Europe and in the Caucasus is controversial. Y. Kleopov and F. Hryn (1933) believed that this species is a relic of the Tertiary period in the Caucasus Mountains and Southern Carpathians and Riss-Wurm relic in other territories of the European part of its range. They attributed *E. nanus* to “wandering” relics, which do not have genesis links with modern forest formations and is in a regressive stage in modern time. According Kleopov’s and Hryn’s opinion (1933), the disjunctive range of *E. nanus*, the rare flowering and the still rarer

fruiting of this species are the confirmation of its relic nature. According to this point of view, *E. nanus* is a species of Chinese origin, which penetrated into Europe in the Neogene period during the invasion of forest trees, similar to modern trees of China's and North American forests. During glaciations it was preserved in the Crimea and Southern Carpathians. The Riss-Wurm interglacial period was the time of intensive settlement of *E. nanus* in the Dnieper and Podolian Uplands and the Moldavian Plateau. From the xerothermic period *E. nanus* has been preserved in the most humid ecotopes. Kleopov's point of view is shared by Leonova (1974).

Other authors attributed *E. nanus* exclusively to Tertiary relics of natural floras of a different region of Europe. Pachoskiy (1910), Szafer (1923), Lavrenko (1930), Gajewski (1937), Wulf (1944), Walter (1974) considered it as a Tertiary relic of the Podolian Upland. Golubev (1991) treated this species as a relic of the Crimean Mountains. Romanian botanists (Pop, 1954; Pascovschi & Donita, 1967; Lungu, 1983) attributed *E. nanus* to Tertiary relics of the flora of Romania, Szatmari, Hurdu (2022) attributed it to glacial relict. The relic nature of *E. nanus* is confirmed by the discovery of its fossils in Neogene deposits in Armenia (Kolakovsky, 1955). The low reproductive potential of *E. nanus* is also indicated the relic nature of this species. According detailed investigation of Shchepotyev (1941) the main way of *E. nanus* reproduction is vegetative. Seed propagation of this species is very low.

Shchepotyev (1941) distinguishes two ecological forms of *E. nanus*: tall and short (Fig. 5). The first grows in well-lit places. The second grows in shady places and does not form flowers and fruits. Seed productivity is less than 0.5–1.0%. This is the cause of difficulties in the spread of this relic species in Europe. However, in Mongolia the plants of *E. nanus* regularly bloom and bear fruits (Prokhanov, 1949).



**Fig. 5.** Two ecological forms of *Euonymus nanus*:

*a* – the form without flowers; *b* – the form with flowers and fruits

All of the above contradicts Didukh's (2008) point of view about the alien origin of *E. nanus* in Europe.

For establishment of the origin of *E. nanus* populations in Europe and in the Caucasus it is necessary to analyze peculiarities of its geographical distribution and habitats in these parts of the range.

At a distance of thousands of kilometers from Central Asia, two small exclaves of *E. nanus* range are situated in the Northern Caucasus and in

the Crimean Mountains. Only 6 localities of *E. nanus* were recorded in the Caucasus in the territories of Karachay-Cherkassia, Kabardino-Balkaria and Stavropol regions of the Russian Federation (checklist, Fig. 1).

The small Crimean exclave of *E. nanus* occupied the Burulcha River valley on Subetkan-yayla and Middle Plateau of Chatyrdag (checklist, Fig. 1). A much larger number of *E. nanus* localities were recorded in the lowland part of Ukraine: in the Dnieper and Podolian Uplands and one locality in the Prut-Dniester interfluvium (Volutsa, 2007) (checklist, Fig. 1). There are nearly 15 localities of *E. nanus* recorded in Cherkasy and Kirovohrad regions in the Dnieper Upland. Only a single locality of *E. nanus* is registered in 2023 in the Dnieper lowland in Kyiv region (checklist, Fig. 1). In 2021 we found three new localities of *E. nanus* near Budamakivka village in Smila district, Cherkasy region: in the ravine Tsyganskyy Yar of Makiivske (69 quarter) and Kapitanivske (18 quarter) forestries and in Sotnickyy Yar (27 and 31 quarter) of Makiivske forestry (checklist, Fig. 1). A single local population in the Dnieper Lowland was recorded in Stovpjiagske forestry, near Kovalyn village, Pereyaslav district, Kyiv region. In the Podolian Upland *E. nanus* was recorded near 45 localities mainly in Khmelnytskyi and Vinnytsia regions. Only two localities for *E. nanus* were found in Odesa and Ternopil regions. One locality is known from Moldova (checklist, Fig. 1).

On the Moldavian Plateau, *E. nanus* was recorded in nearly 15 localities in Moldova and nearly 10 localities in Romania, mainly in Suceava Upland (geomorphologically this Upland is part of the Moldavian Plateau) (checklist, Fig. 1).

The Carpathian part of *E. nanus* range covers the Southern Carpathians in Transylvania and the Western Carpathians in Bucovina. 15 of the 16 localities known in the Carpathian Mountains are concentrated in Romania (checklist, Fig. 1). The single locality of *E. nanus* in the Ukrainian Carpathians is located in the vicinity of Panka village, Storozhynets district, Chernivtsi region (Chomey & Yakymchuk, 1995).

So far, in the European part of *E. nanus* range, including the territories of Romania, Moldova and Ukraine, no more than 100 localities of *E. nanus* have been recorded. In the Caucasus only 6 localities for the species have been found on the territory of the Russian Federation.

The phytocoenotical amplitude of habitats of *E. nanus* is very large. In the mountains of Central Asia it grows in spruce-pine forests, formed by *Picea asperata* Mast. and *Pinus tabuliformis* Carrière together with *Juniperus rigida* Siebold & Zucc., *Rhamnus parvifolia* Bunge, *Ribes pulchellum* Turcz. and other species between 2000–3000 m above sea level (Walter, 1974).

In the Caucasus Mountains *E. nanus* is found at elevations between 1700–2000 m above sea level. In Kabardino-Balkaria it grows on moving and fixed scree slopes of southern exposure among the thickets of *Berberis vulgaris* L., *Spiraea hypericifolia* L., *Rubus bushii* L. H. Bailey (Shkhaapsoev, 1989).

In the Crimean Mountains *E. nanus* grows in hornbeam forests *Carpinus betulus* – *Poa longifolia* Trin. + *Mercurialis perennis* – *Euonymus nanus* and *Carpinus betulus* – *Mercurialis perennis* + *Galium odoratum* (L.) Scop. associations in sinkholes on Chatyrdag Plateau (Golubev, 1991; Isikov & Astafeva, 2019).

According to detailed investigation of habitats of *E. nanus* in the lowland part of Ukraine (Kleopov & Hryn, 1933) it has been shown that in the Dnieper Upland this species is connected with *Carpineto-Quercetum stellarioso-caricosum*, *Carpineto-Quercetum mercurioso-stellariosum*, *Carpineto-Fraxineto-Quercetum mercurialioso-stellariosum*, *Fraxineto-Carpineto-Quercetum caricosum (pilosae) associations*.

According to our investigation in the Kapitanivske and Makiivske forestries, in the Dnieper Upland *E. nanus* grows mainly in hornbeam and hornbeam-oak forests of *Euonymo-nanae-Carpinetum association*. The phytocoenotical amplitude of *E. nanus* habitats in the Podolian Upland is larger, than in the Dnieper Upland. However, all *E. nanus* populations here are confined to deciduous forests According to Kleopov and Hryn (1933), in the Podolian Upland *E. nanus* grows in hornbeam forests *Carpinus betulus-Carex pilosa*, *Carpinus betulus* + *Fraxinus excelsior-Euonymus nanus* + *Aegopodium podagraria* associations, *Carpinus betulus-Corylus avellana-Euonymus nanus* + *Asarum europaeum*, *Carpinus betulus-Corylus avellana-Euonymus nanus* + *Aegopodium podagraria* associations; in oak forests *Quercus robur* + *Tilia cordata-Carex montana*

na L., *Quercus robur* + *Alnus glutinosa* (L.) Gaertn.-*Acer tataricum*-*Aegopodium podagraria* + *Euonymus nanus* associations; in elm forests *Ulmus laevis*-*Corylus avellana* + *Prunus padus* L.-*Aegopodium podagraria* + *Euonymus nanus* associations; in alder forests *Alnus glutinosa*-*Prunus padus*-*Aegopodium podagraria* + *Euonymus nanus* association and in willow forests *Salicetum*. Kovalchuk & Klots (1984) have updated the list of *E. nanus* habitats in the Podolian Upland by including forests communities of *Carpinetum-Quercetum stellarioso-caricosum (pilosae)* and *Carpinetum-Quercetum asarosum* associations.

During our field investigation in the south of the Podolian Upland we found new habitat of *E. nanus* in dumast oak forest *Quercetum (petraea) Caricosum (brevicollis)* in "Karmelukove Podilla" National Nature Park. In Lisnychivka Botanical Reserve in Balta district in Odessa region it grows in communities *Querceto (petraea)-Quercetum (roboris) cornoso (mas) - Quercetum (roboris) cornoso (mas) - Caricosum (brevicollis)* (Ustylenko & Dubyna, 2014).

On the Moldavian Plateau in Moldova and Romania, *E. nanus* grows in dumast oak forest *Quercetum-petraea-caricosum-moldavicum* association; in hornbeam forests *Euonymo-nanae-Carpinetum* and in oak-elm forests *Querceto-Ulmetum euonymotusum nanae* and in wet flood-plain forests *Fraxino-pannonica-Ulmetum glabra* (Simonov, 1961; Kleopov, 1990; Lazu, 1992).

On the Romanian part of the Moldavian Plateau (Suceava Upland) the habitat of *E. nanus* is very similar to its habitats in Moldova. Here it grows in hornbeam forests *Corylo-avellana - caprinetum* and in floodplain forests *Fraxino-pannonica - Ulmetum glabra* (Tomescu & Horeanu, 2009; Coldea & Ursu, 2016).

In the Romanian Carpathians it grows in alder forests *Calamagrosti-Salicetum cineruae-Alnetum incanae* (Soran et al., 1957; Lungu, 1983; Vojtko et al., 2017). In the Ukrainian Carpathians *E. nanus* grows in oak forest *Quercetum roboris* and in *Telekio speciosae - Alnetum incanae* communities (Chomey & Yakymchuk, 1995).

Survey of habitats showed that in the European part of its range *E. nanus* grows only in deciduous forests. This is their difference from Asiatic habitats, connected with coniferous forests and from Caucasian habitats connected with moving and scree slopes. The phytocoenotical amplitude of *E. nanus* habitats is large and represented all types of broad-leaved and narrow-leaved forests of Eastern Europe. Lowland and mountain forests with *E. nanus* in the European part of range are very similar by structure and floristic composition.

According Golubev's (1991) investigation, Crimean plant communities with *E. nanus* are very similar by floristic composition to *Carpinetum-nemorosum*, described by Kleopov (1938, 1990), Kleopov & Hryn (1933), from the lowland part of Ukraine. Golubev (1991) found 79 plant species, common for the Crimean and lowland habitats of *E. nanus* in Ukraine. These data indicate the common origin of lowland and Crimean *E. nanus* populations.

Habitats of *E. nanus* are also habitats for some other rare species of East-European flora: *Carex brevicollis*, *Epipactis atrorubens*, *E. helleborine*, *Lilium martagon*, *Platantera bifolia*, *Scopolia carniolica*, *Sorbus torminalis*. This fact enhances their zoological value.

All of the above contradicts Didukh's (2008) point of view about the alien origin of *E. nanus* in Europe. He came to this conclusion based on the establishment of three local populations of *E. nanus* in the Crimean and Carpathian Mountains and in the Podolian Upland connected with anthropogenically disturbed ecotopes. This hypothesis is insufficiently scientifically substantiated, insofar as most of the 100 or so local populations of *E. nanus* known from the European part of the range are confined to anthropogenically undisturbed or little destroyed habitats in the depth of the woods. Certainly, species belonging to natural floras, especially rare and endangered species, including *E. nanus*, are suffering greatly from anthropogenic pressure. It is not surprising that degradation of some natural habitats of *E. nanus* takes places in the European part of its range. However, this does not allow us to consider transformed ecotopes as the primary habitats of *E. nanus* in Europe.

Anthropogenic disturbance of natural habitats of *E. nanus* leads to elimination of its populations. In the Dnieper Upland the area this plant occupies has been reduced. The local population in Bilogrudivka forestry massif near Uman town occupied 22,000 m<sup>2</sup> in the 1940s (Onychchenko, 1947)

and it was reduced to 3,625 m<sup>2</sup> in the nineties (Butylo, 1992). We did not find *E. nanus* in Bilogrudivka forest during our field research in recent years.

There are mainly small populations of *E. nanus* surviving in the Dnieper Upland. This species has been known here for a long time from the forest massif Kholodnyj Yar in Cherkasy region and Chorny Lis in Kirovohrad region. The density of *E. nanus* local populations in Kholodnyj Yar is 1–3 vegetative shoots per 1 m<sup>2</sup>, seldom it is 5–10 vegetative shoots per 1 m<sup>2</sup>. According Kurson's (1978) investigation, the largest population density of *E. nanus* in Kholodnyj Yar is 25 vegetative shoots per 1 m<sup>2</sup>. Considering that the forest massif Kholodnyj Yar was not under protection for many years, the felling of the trees would have threatened *E. nanus* populations here. During our field investigation at the end of the XX century we confirmed the growth of *E. nanus* in a 150-year old hornbeam forest in Bogdanivske forestry. The density of population was 1–5 vegetative shoots per 1 m<sup>2</sup> (Melnyk, 2000). This habitat was a place of herding cattle to pasture, which negatively affected the state of the *E. nanus* population. So-called sanitary felling led to elimination of the population. We did not find *E. nanus* in Chorny Lis forest massif during our field research in recent years.

The largest populations of *E. nanus* in the Dnieper Upland are situated in hornbeam and in hornbeam – oak forests in Makiivske and Kapitaniivske forestries in Cherkasy region. Shevchyk et al. (2009) indicated that in the vicinity of Pastyrske village the *E. nanus* population occupied a space of 10 ha, the density of the population was 40–50 shoots per 1 m<sup>2</sup>. We have clarified the population parameters of *E. nanus* in this locality and established that this population occupied a space of 23.9 ha in the territory of Makiivske forestry. The average population density is 50 vegetative shoots per 1 m<sup>2</sup>.

Maximum population density is 120 vegetative shoots per 1 m<sup>2</sup>. Substitution of primary hornbeam forest by thickets is leading to degradation of the *E. nanus* population, where its population density is 1–5 shoots per 1 m<sup>2</sup>. In Tsyhanskyi Yar gully in Makiivske and Kapitaniivske forestries the local population of *E. nanus* occupied 42.8 ha. The average population density is 50 vegetative shoots per 1 m<sup>2</sup>, maximum population density is 100 vegetative shoots per 1 m<sup>2</sup>.

In Sotnyckij Yar the local population of *E. nanus* occupied 28.8 ha in Makiivske forestry, average population density is 30 vegetative shoots per 1 m<sup>2</sup>, maximum population density is 70 vegetative shoots per 1 m<sup>2</sup>.

The single local population of *E. nanus* in the Dnieper lowland consists of 40 vegetative shoots.

Six out of eight populations, known from the Podolian Upland within Khmelnytskyi region, have been eliminated. Only two local populations in Satanivske and Cykivske forestries have survived to our days. They occupy only 0.6 ha. Population density is 1–5 vegetative shoots per 1 m<sup>2</sup> (Kovalchuk & Klots, 1984). *E. nanus* is very rare in plant communities in the extreme south of the Podolian Upland in "Karmelyukove Podillya" National Natural park in Vinnytsia region, where population density is 1–5 vegetative shoots per 1 m<sup>2</sup> (our data) and in Odesa region, where density of populations is 1–5 vegetative shoots per 1 m<sup>2</sup> (Ustylenko & Dubyna, 2014). The local *E. nanus* population, known from the wood along the stream in the Southern Bug river valley in the vicinity of Pechera village in Tulchyn district of Vinnytsia region (Balkovsky, 1939) is extinct now. In the floodplain hornbeam forest on the left bank of the Murafa River near the village Vyla Yaruhski on the plain only 300 vegetative shoots of *E. nanus* were found in an area of 0.6 ha.

Local Moldavian populations are also small: 68 shoots per m<sup>2</sup>. The largest population, situated near Comești town, occupied 200 m<sup>2</sup> (Ghendov, 2015).

In the lowland part of Romania in Bixad, Covasna, Rogoneshty settlements in Suceava district and in Bamarului gorge near Suceava city the species has disappeared (Lungu, 1983). In the Romanian Carpathians *E. nanus* populations are also rare. The largest local population extends 2 km along the stream Cibo near Miercurea Ciuc town (Soran et al., 1957). In the valley of Vargyas gorge, the population of *E. nanus* occupied a space of only 4 × 10 m (Vojtko et al., 2017).

The single local population of *E. nanus* in the Ukrainian Carpathians in Komariivske forestry (Chernivtsi region) consists of small curtains 2–10 m<sup>2</sup> distributed over an area of 19.8 ha (Chomey & Yakymchuk, 1995).

Crimean populations of *E. nanus* occupy small areas. Only 700 vegetative shoots were found in Burulza River valley near Simferopol city and about 25–30 thousand shoots in local populations on the Chatyr-Dag plateau (Isikov & Astafeva, 2019).

Regressive change of *E. nanus* populations is taking place in the Caucasian exclave. Three out of four populations, registered in Stavropol Krai of Russian Federation are extinct. One single population has remained here in Hurzuk village near the Kuban River. It occupies a space of 0.03 ha (Mikheev, 2008).

Single population of *E. nanus* in Kabardino-Balkaria consists only of 69 vegetative shoots (Shkhagapsoev, 1989). The largest Caucasian population of *E. nanus* consists of nearly 500 individuals. The total number of *E. nanus* in the Caucasian Mountains is nearly 1000 individuals (Mikheev, 2008).

Overall, regressive changes and elimination of *E. nanus* populations are taking place in all European and Caucasian parts of its range.

*Euonymus nanus* is included in the Red Data Books of Ukraine (Melnyk & Didukh, 2009) and Moldova (Ghendov, 2015) as vulnerable, in the Red Data Book of Russian Federation (Mikheev, 2008) and Red Data List of Romania (Oltean et al., 1994) as endangered.

In Romania, *E. nanus* is under protection in the forest reserve “Pădurea Gheorghitoiu”, in the nature reserve “Pădurea Bălteni” and “Pădurea Ciritei” in Moldova region (Sarbu, 2007).

In Moldova, this species is protected in the reserves “Plaiul Fagului”, “Padurea Domneasca”, “Capriana-Scoreni”, in the Botanical Nature Monument “Harjauca-Sipoteni” (Ghendov, 2015).

In Ukraine *E. nanus* is under protection in the national nature parks “Podilski Tovtry” and “Karmeliukove Podillia”, “Cholodnyj Yar”, in the Crimean Nature Reserve and the natural reserve “Medobory”, in landscape reserves “Ustyanska Dacha”, “Sovyj Yar” and “Ivankovetskyi” in Khmelnytskyi region, in Lisnychivskyi Botanical Reserve in Odesa region (Didukh, 2009; Melnyk & Didukh, 2009; Ustyomenko & Dubyna, 2014). We proposed that botanical reservations should be organized for in situ protection of the largest *E. nanus* populations in Europe in Makiivske and Kapitanivske forestries in Cherkasy region and in Haydamatska Balka Botanical Reserve in Vinnytsia region, in M. M. Gryshko National Botanical Garden of the Ukrainian Academy of Sciences. Our scientific substantiation was presented to the Department of Ecology in Cherkasy, Kyiv and Vinnytsia regional councils.

In the Russian Federation *E. nanus* is under protection in Teberda Nature Reserve and in reserve “Uchkulanskoe Ushchele” (Mikheev, 2008).

Due to the phytosociological value of *E. nanus* populations, it must be included to the European Red List. All European and Caucasian populations of *E. nanus* must be under protection.

*Euonymus nanus* has the ability to form populations in cultivated coenoses. In artificial phytocenoses and the botanical monument of nature for protection of a single local population of *E. nanus* on the left bank of Ukraine in Stivpjagivske forestry in Kyiv region, in “Olexandria” Arboretum (Bila Tserkva city), in Ustyimivsky Arboretum (Poltava region), in “Veseli Bokovenky” Arboretum (Kirovohrad region) and in the abandoned landscape park in Tereshchenko’s estate in Denyshy village (near Zhytomyr city) in Ukraine, homeostatic introduced populations have formed, occupying areas up to 100 m<sup>2</sup>.

Stable introduced populations of *E. nanus* have formed during the last 100 years in some old landscape parks in Moscow, Tver and Oryol regions of the Russian Federation. The area of local introduced populations of *E. nanus* in the Russian Federation ranges from 2.5 to 200.0 m<sup>2</sup> (Makrydin et al., 1993).

Thus, modelling of *E. nanus* populations in cultivated coenoses is an effective method of its *ex situ* conservation.

## Conclusion

The Euro-Asiatic species *Euonymus nanus* (Celastraceae) is a rare species in the European and Caucasian parts of its range, included in the Red Data Books of Ukraine, Moldova, the Russian Federation and in the Red List of Romania.

The European part of the range of *E. nanus* consists of localities in the Carpathian Mountains, Moldovan Plateau, Podolian, Dnieper Uplands

and Dnieper Lowland (Romania, Moldova, Ukraine) and the exclave in the Crimean Mountains (Ukraine). A separate Caucasian exclave of *E. nanus* range occupied the Northern Caucasus in the Russian Federation. There near 100 localities of *E. nanus* in Europe and 6 localities in the Caucasus Mountains.

The peculiarity of European habitats of *E. nanus* is their exclusive confinement to deciduous forests. The phytocoenotical amplitude of European forest habitats of *E. nanus* is very large and included all types of broad-leaves and narrow-leaved forests of Eastern Europe. This is their difference from Caucasian habitats, connected with moving and scree slopes and from Asiatic habitats, connected with coniferous forests.

Biogeographical and paleontological data and some biological peculiarities (low reproductive potential) are confirmation of the relic nature (Tertiary relic) of *E. nanus* in Europe. The claim that *E. nanus* in Europe has an alien origin is insufficiently scientifically substantiated.

Local populations of *E. nanus* in Europe and the Caucasus Mountains are very small in area, its density is low. Regressive change in the *E. nanus* populations are taking place everywhere in the European part of its range and in the Caucasian exclave. Due to the uniqueness of *E. nanus* populations, it must be included to the European Red List. All European and Caucasian populations must be brought under protection.

Modelling of *E. nanus* populations in cultivated coenoses is an effective method of its *ex situ* conservation.

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