ЕКОЛОГІЯ І МОНІТОРИНГ

UDC 630.1:582.912.42:630.221.01:477-924.82/.84
https://doi.org/10.33220/1026-3365.146.2025.48

REGENERATION DYNAMICS OF FOREST COENOSES WITH *RHODODENDRON LUTEUM* SWEET (ERICACEAE) UNDERGROWTH AFTER CLEAR CUTTING IN MOIST RELATIVELY FERTILE OAK-PINE SITE TYPE IN ZHYTOMYR POLISSIA, UKRAINE

Tushak A. Yu.[1], Orlov O. O.[2]*, Zhukovskyi O. V.[3], Zhyzhyn M. P.[4]

The total area of forests with an undergrowth of *Rhododendron luteum* in moist relatively fertile pine site type (C_3) within the Branch "Emilchynske Forestry" of the State Specialized Forest Enterprise "Forests of Ukraine" and the Subsidiary Enterprise "Emilchinske Forestry APK" of the Zhytomyr Regional Communal Agroforestry Enterprise "Zhytomyroblagrolis" is 2,614.4 ha. Of this, 88.2 % consists of forests of natural origin, while 11.8 % comprises forest plantations. The study revealed that *Quercus robur* dominates in 53.5 % of the examined stands, while 46.5 % are secondary forests. Among these secondary stands, *Betula pendula* occupies 28.6 % of the area, and *Pinus sylvestris* covers 14.4 %. In terms of stand structure, forests with relative densities of stocking of 0.61–0.70 and 0.51–0.60 prevail, accounting for 41.1 % and 24.3 % of the total area, respectively. Following clear-cutting in moist relatively fertile pine sites, undergrowth with *Rh. luteum* regenerates sufficiently in stands within 40 years. In stands aged 60–70 years, the formation of a closed *Rh. luteum* undergrowth layer is nearly complete, and the physiognomy of the coenoses closely resembles that of the mother stand. However, in 17 % of the surveyed sites, *Rh. luteum* did not regenerate, primarily due to high stand density, untimely intermediate cutting and insufficient thinning intensity in stands younger than 30 years. A long-term analysis of the distribution of stands with *Rh. luteum* undergrowth revealed a significant decline in area. In the Branch "Emilchynske Forestry" of the SFE "Forests of Ukraine", within the moist relatively fertile pine site type (C_3), the area of forest stands dominated by *Rh. luteum* in the undergrowth decreased 2.2-fold between 1978 and 2018, from 926.0 ha in 1978 to 423.8 ha in 2018.
Keywords: yellow azalea, projective cover, vitality, forest plantations, regeneration.

Introduction. The yellow azalea (*Rhododendron luteum* Sweet) is a relict species with a distinct distribution, primarily found in Eastern Europe, the Caucasus, and Transcaucasia, with small, isolated populations in Central Europe (Global Biodiversity Information Facility, 2025). The species' range is disjunctive (Barbarych, 1962; Orlov and Iakushenko, 2017; Global Biodiversity Information Facility, 2025). The lowland populations are primarily located in Ukraine, specifically in Zhytomyr Polissia, including the eastern part of Rivne region (Sarny district) and the western part of Zhytomyr region (Korosten and Zviagel districts) (Orlov and Iakushenko, 2017; Ukrainian Biodiversity Information Network, 2023; Global Biodiversity Information Facility, 2025; iNaturalist, 2025). *Rh. luteum* is nanophanerophyte, mezotrophic, mezophytic, acidophilous species, and heliophyte. Species is violent according to vital strategy; it can form dense thickets and can suppress the plants of the lower layers. It reproduces by seeds and by the growth of bushes.

In the central part of the *Rh. luteum*'s main distribution area within Ukrainian Polissia, in a moist relatively fertile oak-pine forest site type with yellow azalea, the species forms a dense undergrowth.

[1] Tushak Andriy, Zhytomyr Agricultural Technical Professional College, 96 Pokrovska Street, Zhytomyr, 10031, Ukraine. E-mail: andreytushak@gmail.com, ORCID: https://orcid.org/0009-0004-1909-2854

[2] Orlov Oleksandr, PhD (Biology), Senior Researcher, State Institution "Institute of Environmental Geochemistry of the NAS of Ukraine", 34a Academician Palladin Avenue, Kyiv, 02000, Ukraine; Poliskyi Branch of the Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky, 2 Neskorenykh Street, Dovzhyk, Zhytomyr region, 10004, Ukraine. E-mail: orlov.botany@gmail.com, ORCID: https://orcid.org/0000-0003-2923-5324

[3] Zhukovskyi Oleh, PhD (Agricultural Sciences), Poliskyi Branch of the Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky, 2 Neskorenykh Street, Dovzhyk, Zhytomyr region, 10004, Ukraine. E-mail: zh_oleh2183@ukr.net, ORCID: https://orcid.org/0000-0003-3351-9856

[4] Zhyzhyn Mykola, PhD (Biology), Associated Professor, 96 Zhytomyr Agricultural Technical Professional College, Pokrovska Street, Zhytomyr, 10031, Ukraine. E-mail: zhizhin_academy@ukr.net, ORCID: https://orcid.org/0009-0003-1291-6630

*Correspondence: orlov.botany@gmail.com

Here, *Rh. luteum* thrives in oak, pine-oak, alder, and secondary birch and aspen forests, where its undergrowth closure reaches 0.7–1.0, significantly influencing natural stand regeneration and forest management. As a result, forest inventories allocated the moist relatively fertile oak-pine forest site type with yellow azalea as a distinct classification unit. *Querceto-Pinetum rhododendrosum* (*lutei*), forest coenoses characterized by the dominance of *Rh. luteum* in the undergrowth in this forest type, are listed in the Green Book of Ukraine (Ustimenko, 2009). The specified variant of oak-pine forest site type with yellow azalea is used by Ukrainian forest management (Tkach *et al*., 2024). Additionally, *Rh. luteum* is protected under Resolution 4 of the Bern Convention (*Convention on the Conservation of European Wildlife and Natural Habitats*, 1979; *Interpretation manual of the habitats listed in Resolution No. 4*, 2015). Given that both the species and its communities are legally protected in the European Union and Ukraine, concerns regarding their potential economic use have arisen. These concerns are particularly relevant in the certification of forestry enterprises by FSC. However, is important to note that in Zhytomyr Polissia, the estimated area of forests where *Rh. luteum* dominates the undergrowth is approximately 62.000 ha (Koziakov, 1983), with no more recent data currently available.

The primary method of harvesting mature forests in the study area is clear-cutting (Buzun *et al*., 2018), followed by either plantation forestry or natural regeneration. This type of cutting significantly alters the ecological conditions in which reforestation occurs. Therefore, assessing the regeneration of *Rh. luteum* undergrowth in moist relatively fertile forest sites after clear-cutting is of considerable ecological and practical importance.

In Ukraine, forests with yellow azalea (*Rhododendron luteum* Sweet) undergrowth have a localised distribution (Barbarych, 1962). While the species is considered a relict, it dominates the undergrowth across large areas of Zhytomyr Polissia (Koziakov and Koziakov, 1973; Miakushko, 1978), where it exhibits a strong vitality. Estimates of forested areas containing *R. luteum* undergrowth vary in the region, ranging from 130.000 ha (Barbarych, 1953) to 55.000 ha (Koziakov and Koziakov, 1973) and 62.000 ha (Koziakov, 1983). Unfortunately, more recent data on the species' distribution in Ukraine are unavailable.

In Zhytomyr Polissya, according to the dominant classification, the primary forest association – *Querceto-Pinetum rhododendrosum* (*lutei*) – has been described within the *Querceto-Pineta pteridioso-myrtillosa* group of associations, which is specific to the moist oak-pine azalea forest type. This association is characterised by the absence of a moss layer (Barbarych, 1955; Povarnitsyn, 1959; 1971; Koziakov and Koziakov, 1973; Bradis and Andrienko, 1977; Miakushko, 1978), a high *Rh. luteum* undergrowth closure (0.7–1.0), and a sparse herbaceous-dwarf-shrub layer with a projective cover of 1–10 (up to 20) %. The dominant species in this layer include *Vaccinium myrtillus* L., *Carex brizoides* L., and *Convallaria majalis* L.

In the Green Book of Ukraine, within the moist relatively fertile forest sites, according to the dominant classification, *Querceto* (*roboris*)-*Pineta* (*sylvestris*) *rhododendrosa* (*lutei*) forest coenoses have been identified, where *Rh. luteum* dominates the undergrowth. The restoration potential of this association has been assessed as satisfactory (Ustimenko, 2009), a conclusion was supported by other studies (Orlov and Iakushenko, 2017). Classification of forest communities with *Rh. luteum* undergrowth indicates that moist relatively fertile sites are dominated by floristic association *Serratulo-Pinetum* J. Mat., 1981, specifically the variant *Serratulo-Pinetum* var. *rhododendron luteum*, which lacks distinct diagnostic species (Orlov *et al*., 2000).

Orlov and Iakushenko (2017) demonstrated that in Ukraine, the coenoses with the highest *Rh. luteum* undergrowth closure are located in Zhytomyr region, Korosten district (formerly Emilchyne and Olevsk districts), and exhibit strong regeneration potential after clear-cutting. Similarly, studies in the Anatolian part of *Rh. luteum*'s natural range (Turkey) have highlighted its significant regeneration potential, high vitality, and even invasive capacity (Eşen *et al*., 2006).

The silvicultural significance of *Rh. luteum* and its negative impact on the natural regeneration of the main forest-forming species – Scots pine (*Pinus sylvestris* L.) and pedunculate oak (*Quercus robur* L.) – were pointed out by Schmidt (1927). He observed poor natural regeneration of these species in forests with dense yellow azalea undergrowth. To enhance pine and oak regeneration in such forest communities, he recommended cutting down the *Rh. luteum* undergrowth, creating gaps, and planting Scots pine exclusively within these openings. A similar conclusion was reached by Povarnitsyn (1959, p. 65), who stated: 'There is almost no pine regeneration under the canopy of plantations here, only scattered specimens of pine, aged 2–5 years and reaching 20–30 cm in height, can be found. After pine harvesting, azalea proliferates even more vigorously in this forest type, forming nearly impenetrable thickets that suppress pine growth and hinder natural regeneration. To facilitate the pine regeneration in this type of forest, the undergrowth must be cut down.'

In Central Europe, *Rh. luteum* habitats have been analysed and classified into various types, including Continental Nemoral Pine-Oak Forests (Palearctic Habitats) and Mixed Scots Pine-Pedunculate Oak Forests (Căprar *et al*., 2014). The ecological conditions of the species in Poland are close to those of Ukrainian habitats. Additionally, research indicates that *Rh. luteum* populations from Ukraine served as the primary sources for introducing the species into gardens and parks across Eastern and Central Europe, as well as contributing to the formation of some secondary localities of the species in semi-natural habitats within the region (Piórecki and Dubiel, 2009).

In Ukraine, Important Plant Areas – Emilchynski Lisy (Orlov and Onyshchenko, 2017) and Olevski Lisy (Orlov, 2017) – have been designated to protect forests with *Rh. luteum* undergrowth. Furthermore, forest communities containing *Rh. luteum* are protected within several local forest reserves, including Daniov (226 ha), Olgino (815 ha), Perespa (117 ha), Polomy (347 ha), Sych (344 ha), Tokov Mokh (454 ha), Yuzykhivka (439 ha), among others (Orlov *et al.*, 2015).

This study aimed to investigate the key ecological and silvicultural characteristics of *Rh. luteum* habitats in moist relatively fertile forest sites and to evaluate the success of regeneration of forest coenoses with undergrowth of this species following clear-cutting in Zhytomyr Polissia.

The specific objectives were as follows:

– To characterise, based on field research, forest communities in which *Rh. luteum* dominates the undergrowth within mature maternal forests in the moist relatively fertile oak-pine site.

– To assess the regeneration dynamics of *Rh. luteum* undergrowth in forest plantations of varying ages (1–65 years) and in clear-cut areas left for natural regeneration in the moist relatively fertile forest sites.

– To evaluate the success and duration of *Rh. luteum* undergrowth regeneration after clear-cutting.

– To analyse the long-term dynamics of forested areas with *Rh. luteum* undergrowth in the moist relatively fertile forest sites.

– To propose management strategies for the sustainable use of forests containing *Rh. luteum* undergrowth.

Materials and Methods. The study was conducted primarily in 2024 within Zhytomyr Polissia region in Ukraine, delineated according to the current physical and geographical zoning of Ukraine (Marynych *et al*., 2007).

The distribution of *Rh. luteum* was assessed using multiple sources, including herbarium collections: Herbarium of M. G. Kholodny Institute of Botany, NAS of Ukraine (KW), Herbarium of M.M. Gryshko National Botanical Garden, NAS of Ukraine (KWHA), and Herbarium of Taras Shevchenko National University of Kyiv (KWU). Additional data were obtained from floristic databases such as iNaturalist (iNaturalist, 2025) and UkrBin (Ukrainian Biodiversity Information Network, 2023), as well as standard mensuration descriptions from forest enterprises, and our own field observations conducted between 2000 and 2025. Notably, field research revealed discrepancies in forest classification, where stands with *Rh. luteum* undergrowth were often misclassified as other forest types – such as moist relatively fertile hornbeam-oak-pine, hornbeam-pine-oak, or hornbeam-oak site types – instead of the moist relatively fertile oak-pine forest site type with yellow azalea.

The primary data on *Rh. luteum* undergrowth regeneration were derived from field observations in Korosten district, Zhytomyr region, specifically within the Branches "Emilchynske Forestry" and "Luhyny Forestry" of the State Specialized Forest Enterprise "Forests of Ukraine", as well as the Subsidiary Enterprise "Emilchinske Forestry APK" of the Zhytomyr Regional Communal Agroforestry Enterprise "Zhytomyroblagrolis".

To assess the regeneration dynamics of *Rh. luteum* undergrowth, 30 experimental plots, each of 0.5–1 ha, were established following standard methodology (Forest Inventory Sample Plots, 2007) (Fig. 1, Table 1). These plots represented different forest age groups, including:

– mature maternal forests (130–140 years old)
– young forest plantations (before crown closure): 0–1 year and 4–7 years old
– forest plantations after crown closure, categorised as:
  – 8–10 years old
  – 11–20 years old
  – 21–30 years old
  – 31–40 years old
  – 41–50 years old
  – 51–60 years old
  – 61–70 years old.

Each age group included 3 to 10 study plots. Within each experimental plot, assessments were conducted to evaluate the development of the coenosis floristic composition, coenotic structure, and condition of the *Rh. luteum* undergrowth. This included surveys on 3–10 subplots (10 × 10 m each) to determine projective cover (%), spatial distribution, vitality, and flowering patterns.

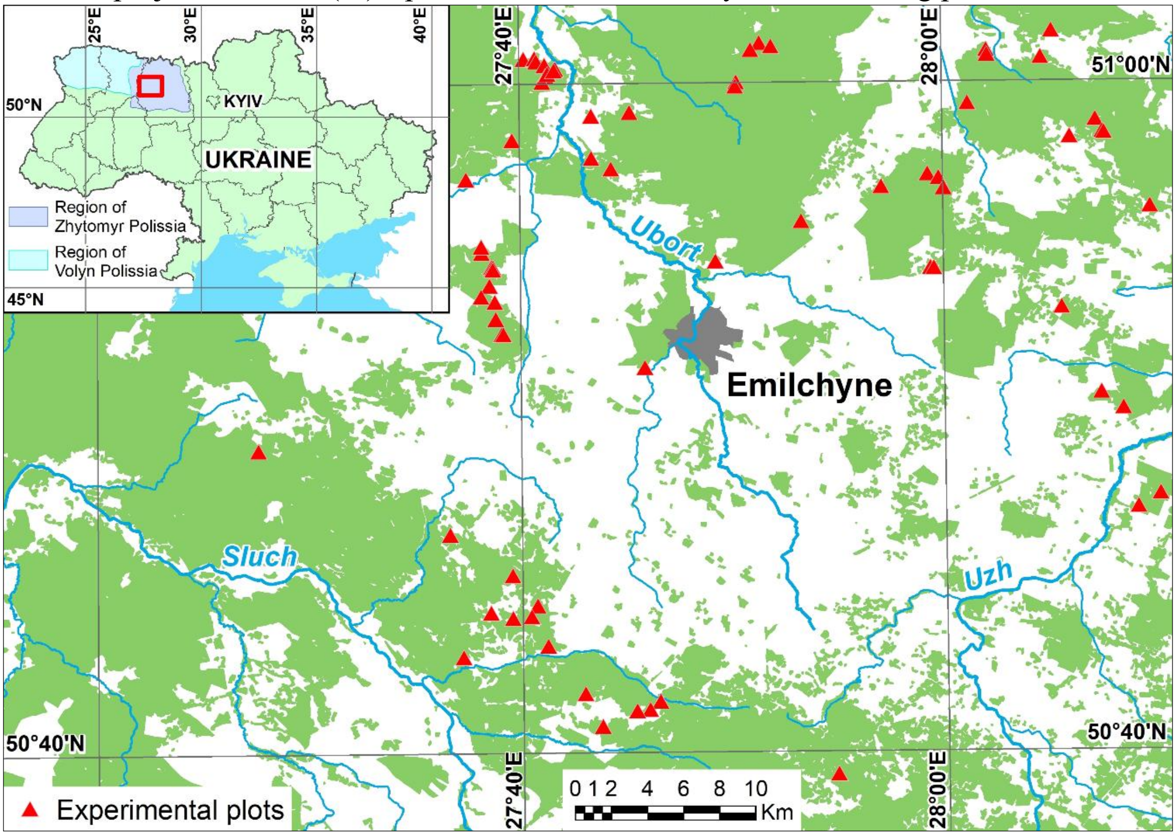

Fig. 1 – Location of the experimental plots of forest communities with *Rhododendron luteum* in the undergrowth in moist relatively fertile oak-pine site type (C_3) in Zhytomyr Polissia

Based on the analysis of spatio-temporal series of forest vegetation with yellow azalea following clear-cutting, the study examined: (1) the impact of the cutting on the extent and rate of *Rh. luteum* undergrowth regeneration and (2) the potential for sustainable management of forest stands with *Rh. luteum* undergrowth, including the feasibility of clear-cutting. Additionally, approximately 120 plots with forest stands up to 30 years old were surveyed using the route method, assessing the presence or absence of *Rh. luteum* undergrowth. The locations of the experimental plots are shown in Figure 1.

Table 1

Brief characteristic of experimental plots of maternal stands and plantations or naturally regenerated stands after clear-cutting in the moist relatively fertile pine site type (C_3) in Zhytomyr Polissia

Age group, years	Branch, Forestry, compartment / subcompartment	Year of clear-cutting	Origin / Age, years	Seedling spacing pattern, m	Forest stand composition	Closure	Geographical coordinates
130–140	BEF, Zhuzhel, 71/5	–	Natural / 140	–	100% Oak + Pine + Birch	0.50	51°00'44.8"N 27°40'41.5"E
	BEF, Harty, 8/22	–	Natural / 130	–	60% Oak 20% Pine 20% Birch	0.60	51°02'28.3"N 27°51'54.9"E
	BEF, Harty, 43/13	–	Natural / 140	–	60% Oak 30% Pine 10% Birch	0.60	51°01'15.0"N 27°51'00.7"E
0–1	BEF, Korolivka, 26/39	2023	Artificial / 1	2,5 × 0,7	80% Pine 20% Birch	–	50°57'16.7"N 27°59'18.0"E
	BEF, Korolivka, 26/42	2023	Artificial / 1	2,5 × 0,7	80% Pine 20% Birch	–	50°57'10.3"N 27°59'49.2"E
	BEF, Korolivka, 32/16	2023	Artificial / 1	2,5 × 0,7	80% Pine 20% Birch	–	50°56'51.4"N 28°00'02.8"E
2–7	BEF, Harty, 43/26	2020	Artificial / 4	3,0 × 0,5	60% Oak 40% Pine	–	51°01'14.2"N 27°51'24.1"E
	BEF, Harty, 65/33	2018	Artificial / 6	3,0 × 0,5	80% Pine 20% Oak	–	50°59'56.7"N 27°50'13.8"E
	BEF, Zhuzhel, 52/36	2018	Artificial / 6	2,5 × 0,7	80% Alder 20% Birch	–	50°55'12.2"N 27°38'09.8"E
	BEF, Zhuzhel, 52/13	2017	Artificial / 6	2,5 × 0,7	80% Birch 20% Aspen	1.0	50°55'01.3"N 27°38'11.0"E
8–10	BEF, Zhuzhel, 62/26	2016	Artificial / 8	2,5 × 0,7	100% Pine	1.0	50°52'34.8"N 27°39'11.5"E
	BEF, Zhuzhel, 62/25	2013	Natural / 10	–	60% Birch 40% Aspen	1.0	50°52'34.4"N 27°39'06.3"E
11–20	BEF, Zhuzhel, 71/6	2010	Artificial / 13	–	60% Oak 20% Aspen 20% Pine	0.75	51°00'43.5"N 27°40'49.7"E
	BEF, Zhuzhel, 62/6	2007	Natural / 16	–	60 % Birch 40% Aspen	0.65	50°53'02.0"N 27°38'49.5"E
	BEF, Zhuzhel, 70/10	2003	Artificial / 20	–	40% Oak 60% Birch	0.70	51°00'48.4"N 27°40'14.4"E

Table 1 (Continued)

Age group, years	Branch, Forestry, compartment / subcompartment	Year of clear-cutting	Origin / Age, years	Seedling spacing pattern, m	Forest stand composition	Closure	Geographical coordinates
21–30	BEF, Zhuzhel, 40/36	2001	Artificial / 22	–	80% Pine 20% Birch	0.70	50°57'30.3"N 27°44'19.7"E
	BEF, Zhuzhel, 77/4	1999	Natural / 24	–	40% Oak 50% Birch 10% Pine	0.75	51°00'18.1"N 27°41'16.2"E
	BEF, Zhuzhel, 71/4	1994	Artificial / 29	–	30% Oak 40% Birch 30% Aspen	0.70	51°00'49.1"N 27°40'45.5"E
31–40	EFA, Emilchyne, 88/22	1992	Artificial / 32	–	100% Pine + Birch	0.62	50°53'16.0"N 28°05'33.9"E
	EFA, Emilchyne, 3/25	1992	Artificial / 32	–	60% Pine 40% Birch + Alder	0.69	51°00'49.9"N 28°02'10.4"E
	EFA, Emilchyne, 104/31	1986	Artificial / 38	–	100% Pine	0.83	50°51'33.7"N 27°45'51.7"E
41–50	BEF, Zhuzhel, 57/27	1982	Artificial / 41	–	30% Oak 70% Birch	0.70	50°54'30.9"N 27°38'42.4"E
	EFA, Emilchyne, 96/6	1979	Artificial / 45	–	50% Pine 20% Birch 30% Alder	0.72	50°54'01.8"N 27°38'33.1"E
	EFA, Emilchyne, 96/23	1978	Natural / 46	–	40% Pine 40% Birch 20% Aspen	0.81	50°53'32.6"N 27°38'48.0"E
51–60	EFA, Serby, 89/43	1973	Natural / 51	–	10% Oak 40% Birch 30% Aspen 10% Pine 10% Alder	0.71	50°44'05.7"N 27°39'32.2"E
	EFA, Serby, 96/17	1973	Natural / 51	–	80% Pine 20% Birch	0.74	50°44'08.4"N 27°40'25.6"E
	BEF, Zhuzhel, 57/16	1965	Natural / 58	–	60% Pine 20% Oak 20% Birch	0.75	50°54'35.0"N 27°38'43.1"E
61–70	BEF, Zhuzhel, 57/15	1960	Natural / 63	–	100% Pine	0.60	50°54'35.5"N 27°38'38.6"E
	EFA, Emilchyne, 20/9	1958	Natural / 66	–	70% Oak 10% Birch 10% Aspen 10% Alder + Pine	0.55	50°59'22.9"N 28°01'13.0"E
	EFA, Emilchyne, 27/27	1958	Natural / 66	–	60% Oak 30% Birch 10% Alder	0.58	50°56'54.8"N 27°57'05.7"E

Notes: 1. BEF is the Branch "Emilchynske Forestry" of SFE "'Forests of Ukraine"; EFA is the Subsidiary Enterprise "Emilchinske Forestry APK" of the Zhytomyr Regional Communal Agroforestry Enterprise "Zhytomyroblagrolis".

2. Oak = pedunculate oak (*Quercus robur* L.), Pine = Scots pine (*Pinus sylvestris* L.), Birch = silver birch (*Betula pendula* Roth.), Alder = black alder (*Alnus glutinosa* (L.) Gaertn.), Aspen = Eurasian aspen (*Populus tremula* L.).

The long-term dynamics of *Rh. luteum* undergrowth areas were analysed based on standard mensuration data from the Branch "Luhyny Forestry" of SFE "Forests of Ukraine" for the period

1978–2018. Statistical analyses were performed using standard variation statistical methods (Horkavyi, 2009). Arithmetic means and their standard errors were calculated, and diagrams were generated using Microsoft Excel, while dependency relationships were analysed using Statistica 10.0 software.

Results. The research results indicate that the total area of forests with *Rh. luteum* undergrowth in the moist relatively fertile pine site type (C_3) in two forestry enterprises – the Branch "Emilchynske Forestry" of SFE "Forests of Ukraine" and the Subsidiary Enterprise "Emilchinske Forestry APK" of the Zhytomyr Regional Communal Agroforestry Enterprise "Zhytomyroblagrolis" – amounts to 2,614.4 ha. Of this total, 88.2% consists of forests of natural origin, while only 11.8% comprises forest plantations. This suggests that over the past 70 years, forests with *Rh. luteum* undergrowth have predominantly developed in areas left for natural regeneration.

The specificity of forest development has been reflected in the species composition of the stands. Natural regeneration in the C_3 edaphotope is diverse, including *Quercus robur* L., *Pinus sylvestris* L., *Betula pendula* Roth, *Populus tremula* L., *Carpinus betulus* L., *Alnus glutinosa* (L.) Gaertn., and *Acer platanoides* L., among others. Consequently, the distribution of forest stands with *Rh. luteum* undergrowth in this edaphotope follows a distinct pattern (Fig. 2).

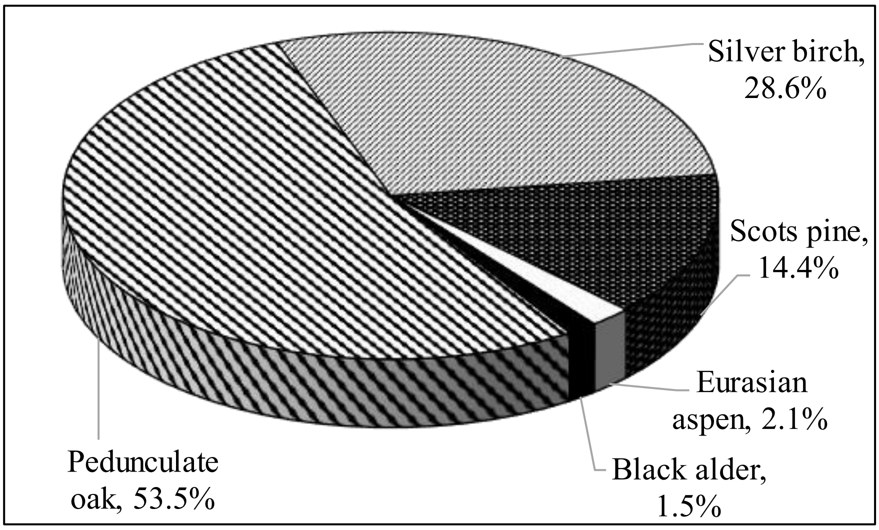

Fig. 2 – Distribution of area of forest stands with *Rhododendron luteum* undergrowth by prevailing tree species in moist relatively fertile pine site type (C_3)

As shown in Figure 2, *Quercus robur* dominates at 53.5 % of the studied stands, and the remaining 46.5 % of the area is represented by secondary stands. Within these, *Betula pendula* occupies 28.6 %, *Pinus sylvestris* 14.4 %, *Populus tremula* 2.1 %, and *Alnus glutinosa* 1.5 %.

The age distribution of stands with *Rh. luteum* undergrowth in moist relatively fertile pine sites is presented in Figure 3.

The data (Fig. 3) indicate that the largest proportion of the studied forests belongs to the 71–80-year age group (29.2%) and the 61–70-year age group (26.8%), together accounting 56% of the total area. The 51–60-year and 41–50-year age groups cover significantly smaller areas, comprising 15.5% and 7.7%, respectively. The remaining age groups occupy only minor portions of the total area. Notably, the 131–140-year-old age group, which represents 1.5% of the area of the studied stands, consists exclusively of oak stands, primarily located within nature reserve fund territories.

The relative density of stocking in forest stands significantly influences the development of *Rh. luteum* undergrowth (Povarnitsyn, 1959). Therefore, we calculated the area distribution for the stands with *Rh. luteum* undergrowth based on relative density of stocking in moist relatively fertile pine sites (C_3) (Fig. 4).

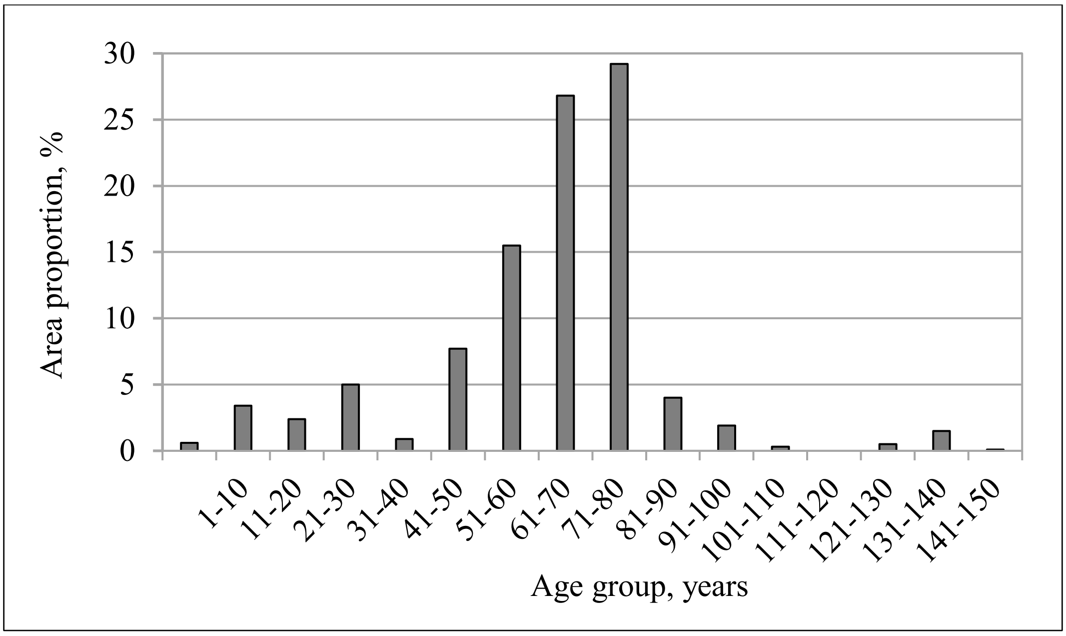

Fig. 3 –Distribution of forest stands with *Rhododendron luteum* undergrowth by age groups in moist relatively fertile pine site type (C_3)

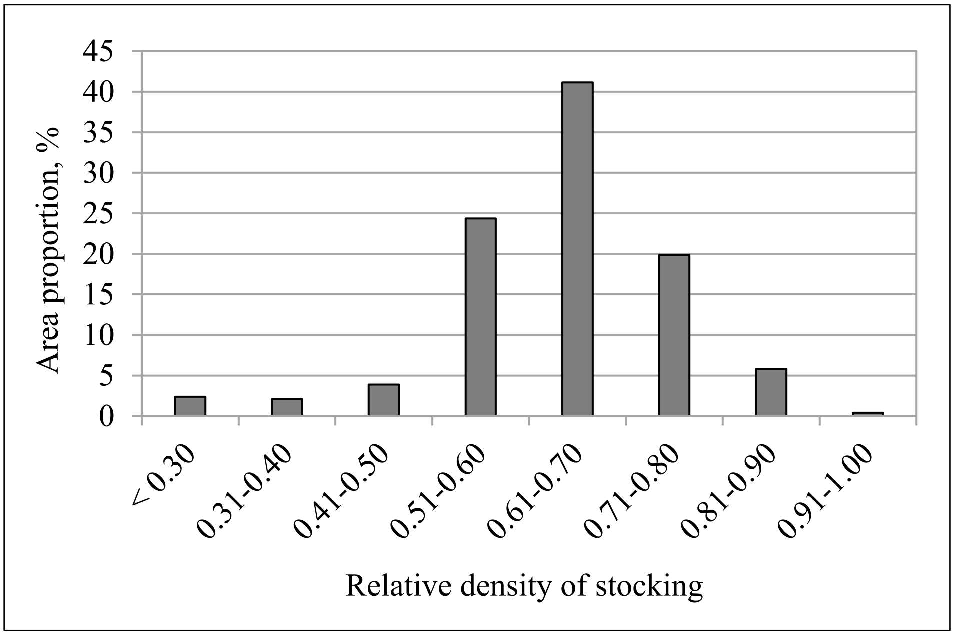

Fig. 4 – Distribution of area of forest stands with *Rhododendron luteum* undergrowth by relative density of stocking in moist relatively fertile pine site type (C_3)

The majority of the studied forest area is occupied by stands with a medium relative density of stocking (0.61–0.70), covering 41.1 %, followed by stands with a low relative density of stocking (0.51–0.60), which account for 24.3 %. (Fig. 4). High-density stands occupy considerably smaller areas; for example, those with a relative density of stocking of 0.81–0.90 cover only 5.8 % of the total area. Notably, sparse stands with a relative density of stocking below 0.30 represent 2.4% of the area. These sparse stands consist of nearly continuous yellow azalea thickets interspersed with single trees remaining from the maternal canopy.

To evaluate the current forest management practices in the studied forestry enterprises operating in forests with *Rh. luteum* undergrowth in moist relatively fertile pine sites, we analysed the distribution of forest plantations in moist relatively fertile pine sites based on dominant tree species

(*Q. robur*, *P. sylvestris*, and *B. pendula*). Additionally, we assessed the area of unclosed plantations replacing stands with closed *Rh. luteum* undergrowth (Fig. 5).

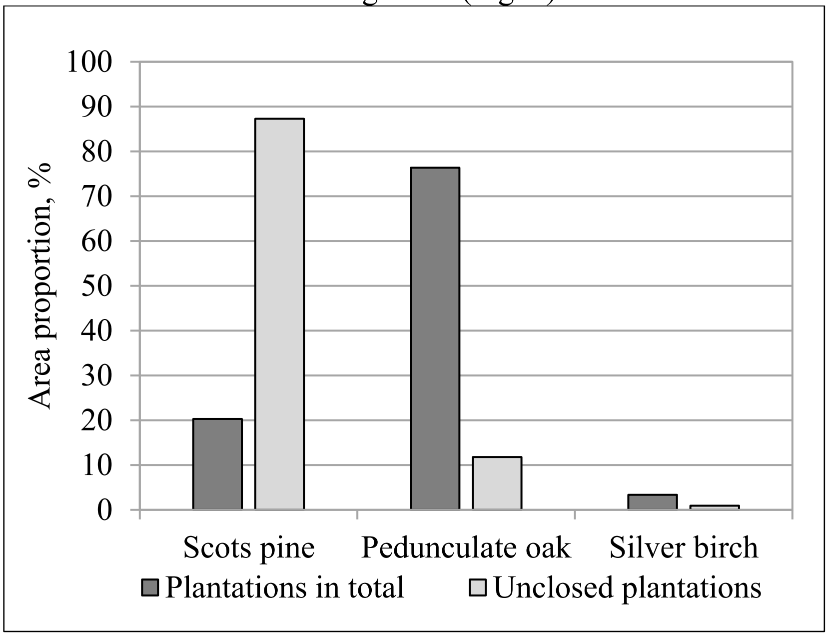

Fig. 5 – Distribution of the entire area of forest plantations and the area of unclosed plantations with *Rhododendron luteum* undergrowth by prevailing tree species in moist relatively fertile pine site type (C_3)

The results of surveys evaluating the condition of *Rh. luteum* undergrowth in experimental plots – encompassing mature maternal stands, forest plantations of different ages, and stands regenerated naturally after final clear-cutting – are summarised in Table 2.

Table 2

Characteristic of undergrowth with *Rhododendron luteum* on experimental plots in maternal stands, forest plantations of different ages and stands regenerated naturally after clear-cutting in a moist relatively fertile pine site type (C_3)

Age group, years	Branch, forestry, compartment / subcompartment	Origin / Age, years	Phase of coenosis formation	Characteristics of undergrowth with *Rhododendron luteum*	
				Projective cover, % (placement by area)	Vitality / Flowering abundance
130–140	BEF, Zhuzhel, 71/5	Natural / 140	Fully developed	80–90 (100) (even)	High / mass
	BEF, Harty, 8/22	Natural / 130	Fully developed	80–90 (even)	High / mass
	BEF, Harty, 43/13	Natural / 140	Fully developed	80–90 (100) (even)	High / mass
0–1	BEF, Korolivka, 26/39	Artificial / 1	Undeveloped	10–15 (20) (uneven, the species is preserved in inter-row spacing)	Sufficient / mass
	BEF, Korolivka, 26/42	Artificial / 1	Undeveloped	(10) 15–20 (25) (uneven, the species is preserved in inter-row spacing)	Sufficient / mass
	BEF, Korolivka, 32/16	Artificial / 1	Undeveloped	15–20 (25) (uneven, the species is preserved in inter-row spacing)	Sufficient / mass

Table 2 (Continued)

Age group, years	Branch, forestry, compartment / subcompartment	Origin / Age, years	Phase of coenosis formation	Characteristics of undergrowth with *Rhododendron luteum*	
				Projective cover, % (placement by area)	Vitality / Flowering abundance
2–7	BEF, Harty, 43/26	Artificial / 4	Undeveloped	15–20 (uneven, the species is preserved in inter-row spacing)	Sufficient / mass
	BEF, Harty, 65/33	Artificial / 6	Undeveloped	15–20 (uneven, the species is preserved in inter-row spacing)	Suppressed / slightly suppressed
	BEF, Zhuzhel, 52/36	Artificial / 6	Undeveloped	10–15 (20) (in groups)	Suppressed / slightly suppressed
	BEF, Zhuzhel, 52/13	Artificial / 6	Undeveloped	10–15 (20) (in groups)	Suppressed / slightly suppressed
8–10	BEF, Zhuzhel, 62/26	Artificial / 8	Active formation stage	10–15 (20) (in groups)	Suppressed / slightly suppressed
	BEF, Zhuzhel, 62/25	Natural / 10	Active formation stage	15–20 (in groups)	Suppressed / slightly suppressed
11–20	BEF, Zhuzhel, 71/6	Artificial / 13	Active formation stage	15–25 (in groups)	Suppressed / slightly suppressed
	BEF, Zhuzhel, 62/6	Natural / 16	Active formation stage	15–20 (in groups)	Suppressed / slightly suppressed
	BEF, Zhuzhel, 70/10	Artificial / 20	Active formation stage	(20) 25–30 (even)	Suppressed / slightly suppressed
21–30	BEF, Zhuzhel, 40/36	Artificial / 22	Active formation stage	(20) 25–30(35) (even)	Slightly suppressed / slightly suppressed
	BEF, Zhuzhel, 77/4	Natural / 24	Active formation stage	(20) 25–30(35) (even)	Slightly suppressed / slightly suppressed
	BEF, Zhuzhel, 71/4	Artificial / 29	Active formation stage	40–45 (50) (even)	Slightly suppressed / slightly suppressed
31–40	EFA, Emilchyne, 88/22	Artificial / 32	Active formation stage	(40) 45–50 (even)	Sufficient / slightly suppressed
	EFA, Emilchyne, 3/25	Artificial / 32	Active formation stage	40–50 (even)	Sufficient / slightly suppressed
	EFA, Emilchyne, 104/31	Artificial / 38	Active formation stage	40–50 (even)	Sufficient / mass
41–50	BEF, Zhuzhel, 57/27	Artificial / 41	Fully developed	45–50 (even)	Sufficient / mass
	EFA, Emilchyne, 96/6	Artificial / 45	Fully developed	50–60 (even)	Sufficient / mass
	EFA, Emilchyne, 96/23	Natural / 46	Fully developed	50–60 (even)	Sufficient / mass

Table 2 (Continued)

Age group, years	Branch, forestry, compartment / subcompartment	Origin / Age, years	Phase of coenosis formation	Characteristics of undergrowth with *Rhododendron luteum*	
				Projective cover, % (placement by area)	Vitality / Flowering abundance
51–60	EFA, Serby, 89/43	Natural / 51	Fully developed	55–65 (even)	Sufficient / mass
	EFA, Serby, 96/17	Natural / 51	Fully developed	55–60 (even)	Sufficient / mass
	BEF, Zhuzhel, 57/16	Natural / 58	Fully developed	60–70 (even)	Sufficient / mass
61–70	BEF, Zhuzhel, 57/15	Natural / 63	Fully developed	70–75 (even)	Sufficient / mass
	EFA, Emilchyne, 20/9	Natural / 66	Fully developed	70–80 (even)	Sufficient / mass
	EFA, Emilchyne, 27/27	Natural / 66	Fully developed	80–90 (even)	Sufficient / mass

Note. BEF is the Branch "Emilchynske Forestry" of SFE "'Forests of Ukraine"; EFA is the Subsidiary Enterprise "Emilchinske Forestry APK" of the Zhytomyr Regional Communal Agroforestry Enterprise "Zhytomyroblagrolis".

By examining a large number of survey subplots with *Rh. luteum* undergrowth, we were able to determine the functional relationship between stand age and the projective cover of this species (Fig. 6).

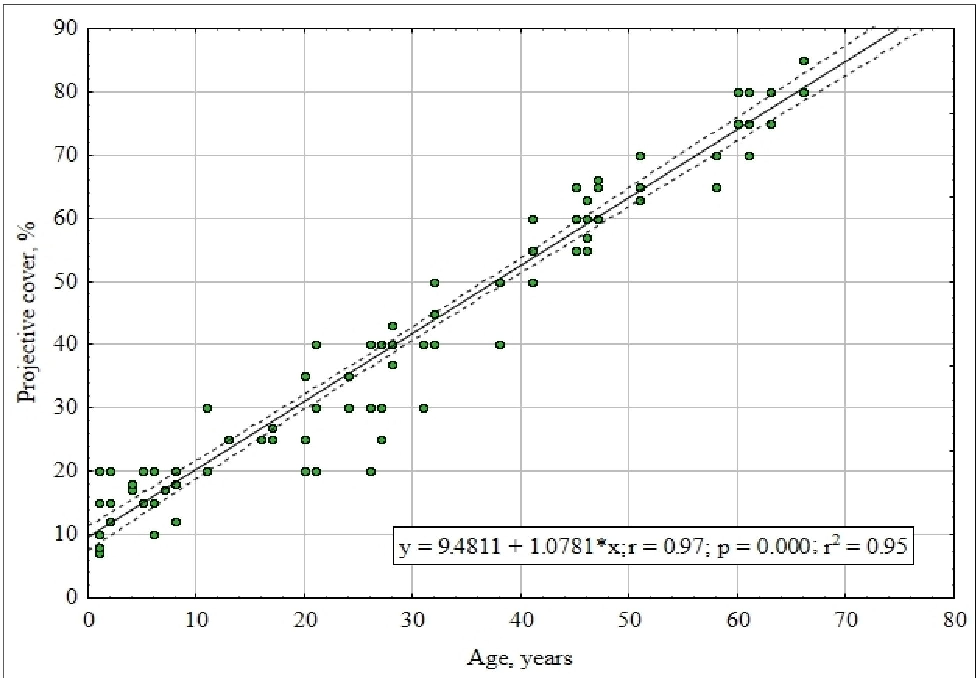

Fig. 6 – Relationship between the age of plantations and naturally regenerated stands and *Rhododendron luteum* projective cover

The long-term dynamics of forest communities with *Rh. luteum* undergrowth is of significant interest. Based on the standard mensuration descriptions from the Branch "Luhyny Forestry" of SFE "Forests of Ukraine", the changes in the communities over a 40-year period (1978–2018) within the moist relatively fertile pine site type (C_3) were revealed (Fig. 7).

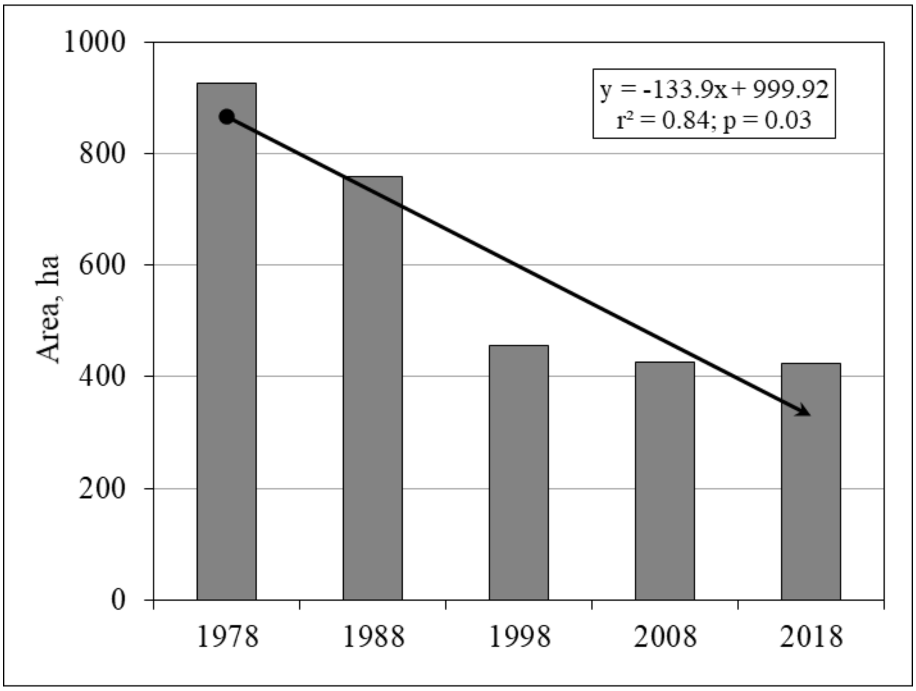

Fig. 7 – Long-term dynamics of area of forest stands with *Rhododendron luteum* in undergrowth in moist relatively fertile oak-pine site type with yellow azalea (С₃ДСА) in the Branch "Luhyny Forestry" of SFE "Forests of Ukraine" (1978–2018)

Discussion. An analysis of the area distribution by dominant tree species (*Q. robur*, *P. sylvestris*, and *B. pendula*) in forest plantations over the past 70 years, as well as unclosed plantations established after clear-cutting of stands with closed *Rh. luteum* undergrowth in the moist relatively fertile oak-pine site type (C_3) (Fig. 5), revealed notable trends. Over this period, *Q. robur*-dominated plantations were established on 76.3% of the area, while pine (*P. sylvestris*) plantations occupied a significantly smaller portion (20.3%), and silver birch (*B. pendula*) plantations were minimal (3.37%). However, an analysis of unclosed forest plantations up to 7 years old showed the opposite pattern, with Scots pine plantations prevailing (87.3%), while pedunculate oak and silver birch occupied only 11.8% and 0.9% of the area, respectively. This discrepancy indicates an unsatisfactory level of forest management in the studied enterprises regarding the conservation of forest ecosystems with *Rh. luteum* undergrowth.

The assessment of the *Rh. luteum* undergrowth conditions in maternal stands, forest plantations of various ages, and naturally regenerated stands after final clear-cutting (Table 2) revealed significant patterns. In maternal stands, the floristic composition and coenotic structure were well-established, with *Rh. luteum* undergrowth exhibiting a high projective cover of 80–90% (up to 100%), even spatial distribution, high vitality, and mass flowering (Fig. 8).

In newly established forest plantations (0–1 year old), the coenosis had not yet formed. The *Rh. luteum* undergrowth displayed a lower projective cover of 10–20% (up to 25%) and was confined primarily to inter-row spaces. However, it demonstrated strong vitality, rapid regeneration from the root systems, and successful flowering and fruiting (Fig. 9).

In the 2–7-year age group, the parameters of the *Rh. luteum* undergrowth remained consistent with those observed in the previous age group. However, in young stands that developed through natural regeneration, its projective cover was lower than in plantations (5–15%) and exhibited highly uneven distribution, often occurring in clusters due to competition with the dense advance growth of tree species. The vitality of *Rh. luteum* undergrowth was slightly suppressed. In the 8–10-year age group, the forest coenosis was in an active formation stage. The projective cover of *Rh. luteum* undergrowth ranged from 10% to 20 %, though it experienced some suppression. Flowering was also reduced due to the increasing closure of the young stand canopy. The levels of forest coenosis development in the 11–20, 21–30 and 31–40-year age groups followed a similar trend: the coenosis remained in an active formation phase, with the floristic composition regenerating, and the coenotic structure developing.

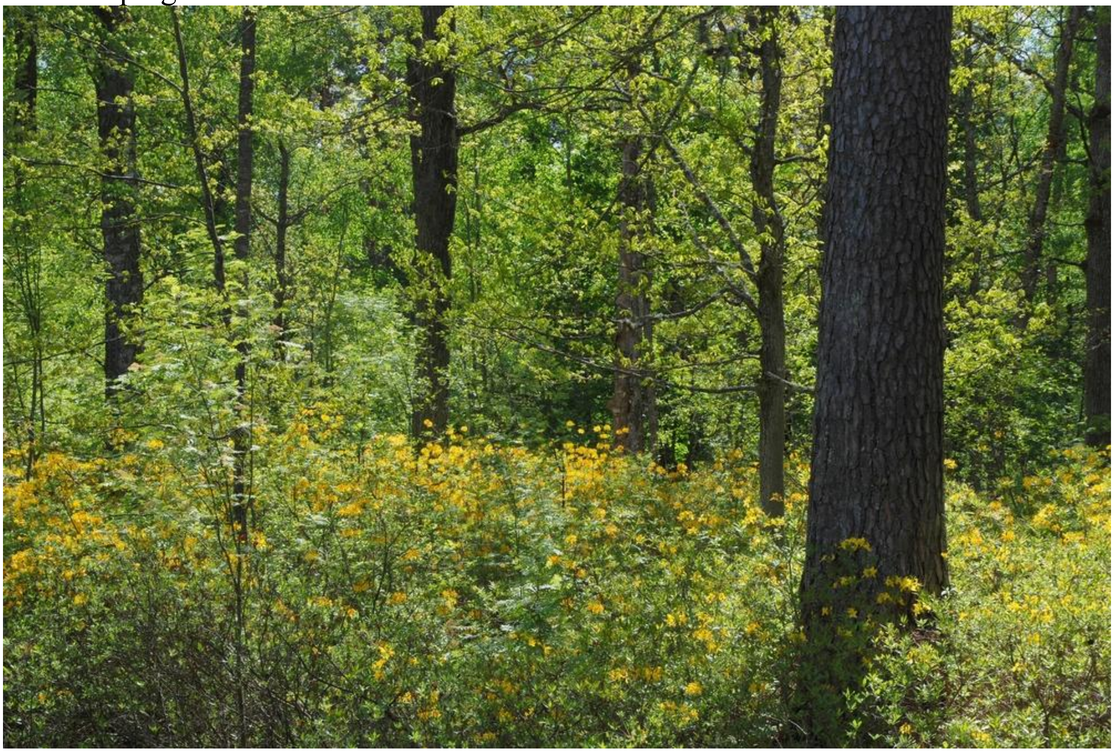

Fig. 8 – Closed undergrowth with *Rhododendron luteum* in 130-year maternal oak stands (Harty Forestry, compartment 18, subcompartment 22)

Fig. 9 – Remains of undergrowth with *Rhododendron luteum* in inter-row spacing of forest plantations established in current year (Harty Forestry, compartment 43, subcompartment 29)

The projective cover of *Rh. luteum* undergrowth gradually increased, from approximately 15% at 20 years to 50% at 40 years. By the age of 20, *Rh. luteum* distribution became more even, though its vitality remained slightly suppressed. In stands older than 40 years, the forest coenosis reached a fully developed state, characterised by a typical floristic composition and coenotic structure. The *Rh. luteum* undergrowth exhibited a projective cover of approximately 45% at 41 years, increasing to 60–70% at 58 years and 80–90 % at 66 years. The species displayed high vitality, even distribution, and mass flowering. These findings indicate that after clear-cutting in the moist relatively fertile oak-pine sites, *Rh. luteum* undergrowth regenerates satisfactorily within 40 years. By the 60–70-year age group, the development of a closed *Rh. luteum* undergrowth is nearly complete, and the physiognomy of the coenosis closely resembles that of the original (maternal) stands (Fig. 10).

Fig. 10 – Closed undergrowth with *Rhododendron luteum* in 63-year-old oak stand in the moist relatively fertile oak-pine site (Zhuzhel Forestry, compartment 57, subcompartment 15)

However, in 17% of the surveyed plots, *Rh. luteum* failed to regenerate. This was primarily attributed to the growth of stand density, as well as untimely and insufficient thinning in stands younger than 30 years.

The analysis of a large number of survey plots with *Rh. luteum* undergrowth revealed a strong linear relationship (r = 0.97) between forest plantation age and *Rh. luteum* projective cover, which was significant (p = 0.000) (see Fig. 6).

The analysis of the long-term dynamics of forest plantations with *Rh. luteum* dominating in the undergrowth (see Fig. 7) indicates a significant decline in their area between 1978 and 2018 in the Branch "Luhyny Forestry" of the SFE "Forests of Ukraine" within the moist relatively fertile pine site type. Over this period, the area decreased 2.2-fold, from 926.0 ha in 1978 to 423.8 ha in 2018. This decline followed a consistent, linear trend, well approximated by a regression equation with a strong relationship (r^2 = 0.84) and statistical significance (p = 0.03). The primary causes of this decline likely stem from forest management planning errors, particularly the misidentification of the moist relatively fertile oak-pine site type with yellow azalea leading to its inclusion in the more common moist relatively fertile oak-pine site type. Additionally, *Rh. luteum* regeneration failure in approximately 17% of felled plots within this site type may have contributed to the reduction in its area. Climate change is another potential factor, as increasing aridity in the region (Didukh, 2023) suppresses *Rh. luteum* regeneration. Given that soil moisture is a critical limiting factor for the establishment of dense *Rh. luteum* undergrowth (Orlov *et al*., 2000), drier conditions may further hinder its recovery.

To enhance *Rh. luteum* regeneration in the undergrowth, intensive thinning of 35-40 % of the stand volume should be conducted, particularly in naturally regenerated stands. In forest plantations established using 2.5 × 0.7 m planting pattern, *Rh. luteum* successfully regenerates in the inter-row spacing; however, in some plots, it may suppress seedlings within the rows. To mitigate this, we recommend maintaining 2-metre-wide corridors (1 m on each side of the row) in younger plantations, with periodic mowing of *Rh. luteum* within these corridors to prevent competition with tree seedlings.

The authors' practical recommendations regarding the implementation of cuttings and the management of forest plantations containing thickets of *Rh. luteum* contradict the official forestry regulations of Ukraine. However, the authors emphasize that this article addresses a problematic issue and is specifically aimed at resolving the discrepancy between the Green Book of Ukraine, Bern Convention, and the practical needs of Ukrainian forestry.

Conclusions. The current characteristics of plantations with *Rh. Luteum*-dominated undergrowth in the moist relatively fertile oak-pine forest site type (C_3) in Ukrainian Polissia remain insufficiently studied. In the Branch "Emilchynske Forestry" of SFE "'Forests of Ukraine" and the Subsidiary Enterprise "Yemilchinskyi Forestry APK" of Zhytomyr Regional Communal Agroforestry Enterprise "Zhytomyroblagrolis", such forests cover 2,614.4 ha, with 88.2% being naturally originated and only 11.8% planted. *Quercus robur* dominates 53.5% of the studied area, while the remaining 46.5% of the area is covered by secondary stands, in which *Betula pendula* occupies 28.6%, *Pinus sylvestris* 14.4%, *Populus tremula* 2.1%, and *Alnus glutinosa* 1.5%. Most studied forests fall within relative stocking densities of 0.61–0.70 (41.1 % of the area) and 0.51–0.60 (24.3%). Following clear-cutting, *Rh. luteum* undergrowth regenerates satisfactorily within 40 years in those forests. By 60–70 years, the undergrowth becomes fully established, and the physiognomy of the coenosis closely resembles that of maternal stands. However, in 17% of surveyed plots, *Rh. luteum* failed to regenerate, primarily due to excessive stand density, as well as untimely and insufficient thinning in stands under 30 years old. In the Branch "Luhyny Forestry" of the SFE "Forests of Ukraine", the area of forest stands with *Rh. Luteum*-dominated undergrowth in moist relatively fertile pine sites (C_3) declined 2.2 times between 1978 and 2018, from 926.0 ha to 423.8 ha. This decrease followed a linear trend with a strong correlation ($r^2 = 0.84$, $p = 0.03$). To enhance *Rh. luteum* regeneration, intensive thinning of 35–40 % of the stand volume is recommended in young stands, especially in naturally regenerated forests. In plantations established according to a 2.5 × 0.7 m spacing pattern, *Rh. luteum* regenerates well in inter-row spaces but may suppress seedlings within the rows. To prevent this, we recommend maintaining 2-metre-wide corridors (1 metre on each side of the row) in younger plantations, with periodic mowing of *Rh. luteum* in these corridors.

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ДИНАМІКА ВІДНОВЛЕННЯ ЛІСОВИХ ЦЕНОЗІВ З ПІДЛІСКОМ *RHODODENDRON LUTEUM* SWEET (ERICACEAE) ПІСЛЯ СУЦІЛЬНИХ РУБОК У ВОЛОГОМУ СУГРУДІ ЖИТОМИРСЬКОГО ПОЛІССЯ, УКРАЇНА

Тушак А. Ю.[1], Орлов О. О.[2]*, Жуковський О. В.[3], Жижин М. П[4]

Виявлено, що площа лісів із підліском *Rhododendron luteum* в едафотопі вологий сугруд (C_3) у філії «Ємільчинське лісове господарство» ДП «Ліси України» та ДП «Ємільчинський лісгосп АПК» Житомирського обласного комунального агролісогосподарського підприємства «Житомироблагроліс» сумарно становить 2 614,4 га, з них 88,2 % площі займають ліси природного походження та 11,8 % – штучного. Виявлено, що на 53,5 % площі досліджуваних насаджень домінує *Quercus robur*, а решта 46,5 % площі представлено похідними насадженнями, в яких *Betula pendula* росте на 28,6 % площі, *Pinus sylvestris* – 14,4 %. Продемонстровано, що у складі досліджених лісів переважають насадження відносною повнотою 0,61–0,70 (41,1 % площі) та 0,51–0,60 (24,3 %). Після суцільних рубок в едафотопі C_3 підлісок з *Rh. luteum* задовільно відновлюється у насадженнях протягом 40 років. У віковій групі 60–70 років формування зімкненого підліску з *Rh. luteum* практично закінчується, а фізіономічність ценозів стає подібною до материнських. На 17 % обстежених ділянок цей вид не відновився, що пов'язане переважно із загущеністю деревостанів, невчасним проведенням та недостатньою інтенсивністю рубок догляду у вікових групах насаджень до 30 років. Розглянуто багаторічну динаміку поширення насаджень із підліском *Rh. luteum* і виявлено, що у філії «Лугинське лісове господарство» ДП «Ліси України» в едафотопі вологий сугруд (C_3) протягом 1978–2018 рр. площі лісових насаджень із домінуванням *Rh. luteum* у підліску зменшилися у 2,2 разу – з 926,0 га у 1978 р. до 423,8 га у 2018 р.

К л ю ч о в і с л о в а : рододендрон жовтий, проективне покриття, життєвість, лісові культури, відновлення.

Одержано редколегією 05.02.2025

[1] Тушак Андрій Юрійович, Житомирський агротехнічний фаховий коледж, вул. Покровська, 96, Житомир, 10031, Україна. E-mail: andreytushak@gmail.com, ORCID: https://orcid.org/0009-0004-1909-2854

[2] Орлов Олександр Олександрович, кандидат біологічних наук, старший науковий співробітник, ДУ «Інститут геохімії навколишнього середовища НАН України», пр-т Академіка Палладіна, 34а, Київ, 02000, Україна; Поліський філіал Українського ордена «Знак Пошани» науково-дослідного інституту лісового господарства та агролісомеліорації ім. Г. М. Висоцького, вул. Нескорених, 2, с. Довжик, Житомирська обл., 10004, Україна. E-mail: orlov.botany@gmail.com, ORCID: https://orcid.org/0000-0003-2923-5324

[3] Жуковський Олег Валерійович, кандидат сільськогосподарських наук, Поліський філіал Українського ордена «Знак Пошани» науково-дослідного інституту лісового господарства та агролісомеліорації ім. Г. М. Висоцького, вул. Нескорених, 2, с. Довжик, Житомирська обл., 10004, Україна, E-mail: zh_oleh2183@ukr.net, ORCID: https://orcid.org/0000-0003-3351-9856

[4] Жижин Микола Павлович, кандидат біологічних наук, доцент, Житомирський агротехнічний фаховий коледж, вул. Покровська, 96, Житомир, 10031, Україна. E-mail: zhizhin_academy@ukr.net, ORCID: https://orcid.org/0009-0003-1291-6630

*Адреса для кореспонденції: orlov.botany@gmail.com