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REGENERATION OF *RHODODENDRON LUTEUM* SWEET (ERICACEAE) UNDERGROWTH AFTER MAIN CLEAR CUTTINGS IN UKRAINIAN POLISSIA

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Background. The yellow azalea (*Rhododendron luteum* Sweet) is a relict species**,** fragmentally distributed in Ukraine, particularly in the Zhytomyr Polissia, covering an area of approximately 62.000 ha. The central part of the species' subrange is located in the Korosten' district of Zhytomyr region, where it forms an understory with a canopy closure of 0.8–0.9 (up to 1.0) in the moist fairly infertile oak-pine site type (B_3) and moist fairly fertile oak-pine site type (C_3). These forest communities are rare and have been included in the Green Book of Ukraine (2009). Additionally, the species is listed in the Bern Convention (Convention..., 1979). Excluding such large forest areas from forest use is impractical, therefore it is necessary to analyze their impact on the species' population.

The aim of this study was to: (1) characterize the communities dominated by *R. luteum* in the understory of mature parent forests within the moist fairly infertile oak-pine site type (B_3) based on field studies; (2) investigate the dynamics of *R. luteum* understory regeneration in forest plantations of different ages (1–65 years) following main clear-cutting, assessing canopy closure and species viability; (3) evaluate the success of *R. luteum* understory regeneration after clear-cutting in the B_3 site type; (4) analyze the long-term dynamics of forest areas with an understory dominated by *R. luteum* in the moist fairly infertile pine site type (B_3).

Materials and Methods. The distribution of *R. luteum* was assessed based on herbarium collections from the 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). Additionally, floristic databases iNaturalist and UkrBin, standard forest enterprise taxation descriptions, and our own field observations (2000–2025) were utilized.

The primary sources of data on the regeneration of *R. luteum* understory were field observations conducted in 2025 in the Korosten' district of Zhytomyr region, particularly in Branch "Emil'chynske Forestry" and Branch "Luhynske Forestry" of the State Enterprise "Forests of Ukraine" as well as Emil'chynske Forestry of the municipal enterprise "Zhytomyroblagrolis". The long-term dynamics of *R. luteum* understory area were studied based on standard taxation descriptions of Branch "Luhynske Forestry" of SE "Forests of Ukraine" for the period of 1978–2018.

Statistical data processing was performed using standard methods of variation statistics (Horkavyi, 2009). The calculation of arithmetic means and their errors, as well as the construction of diagrams, was carried out using Excel software.

Results and Discussion. In mature parent pine forests aged 97–107 years, the condition of the *R. luteum* understory was good, with a canopy closure of 0.8–0.9 (up to 1.0) and a uniform distribution. After main clear-cutting in the B_3 edaphotope, the condition of the *R. luteum* understory in 1-year-old forest plantations was satisfactory, the species was primarily preserved in inter-row spaces, with a projective cover of 10–15 %. In 2–4-year-old forest plantations, the projective cover slightly increased to 17–20 %, while in the 8–16-year-old group, it reached 20–25(30) %. The limiting factor for its development was the high canopy closure of young tree stands. In 21–26-year-old plantations, the condition of the *R. luteum* understory remained satisfactory, with the continuing formation of this layer, its canopy closure slowly increasing to 25–30 %, and distribution transitioning from clumped to uniform. As the plantations aged up to 65 years, the projective cover of the species gradually increased to 65–85 %, maintaining a uniform distribution. In 60–65 year-old plantations, *R. luteum* reached a quasi-equilibrium state, forming a specific lower layer of phytocenoses. Physiognomically, these communities were nearly indistinguishable from parent stands.

It was found that in the Branch "Luhynske Forestry" of SE "Forests of Ukraine", within the most common edaphotope for *R. luteum* in the region – the moist fairly infertile pine site type (B_3) – the area of forests with an *R. luteum* understory significantly decreased from 798 ha in 1978 to 527.2 ha in 2018.

Conclusions. After main clear-cutting and the establishment of forest plantations, a relatively closed *R. luteum* understory is restored within the period of about 40 years in most sites. By the age of 60–65 years, the understory reaches a quasi-equilibrium state. However, in about 15 % of the plots, the *R. luteum* understory does not regenerate after clear-cutting.

Between 1978 and 2018, the area of *R. luteum* in the B_3 edaphotope within the Branch "Luhynske Forestry" of SE "Forests of Ukraine" significantly decreased. In the moist fairly infertile pine site type (B_3), the forest area with the *R. luteum* understory decreased from 798 ha in 1978 to 527.2 ha in 2018, a 1.5-fold reduction.

When forest plantations are established using the 2.5×0.7 m planting scheme, the yellow azalea regenerates satisfactorily in the inter-row spaces, but it may suppress seedlings in the rows. It is recommended to maintain 2-meter-wide corridors (1 meter on each side of the row) in young forest plantations by mowing *R. luteum* shrubs in these areas.

A limiting factor for the regeneration of *R. luteum* populations in young stands is the high density of young tree plantations, including both planted forests and natural regeneration, especially of birch and aspen. To support *R. luteum* understory regeneration, we recommend to conduct intermediate cuttings in young tree canopies.

Keywords: yellow azalea (*Rhododendron luteum* Sweet), forest plantations, understory, projective cover, edaphotope, moist fairly infertile pine site type (B_3)

INTRODUCTION

The yellow azalea (*Rhododendron luteum* Sweet), or Pontic azalea (*Azalea pontica* L.), is a relict species with a specific distribution mainly in Eastern Europe, the Caucasus, and Transcaucasia, with small exclaves in Central Europe (POWO, 2025). The species is characterized by a disjunct distribution (Barbarych, 1962; Orlov & Yakushenko, 2017) and a localized presence in Ukraine (Orlov & Yakushenko, 2017; UkrBIN; iNaturalist).

The lowland population of this species is primarily found in the Zhytomyr Polissia region, particularly in the eastern part of Rivne region (Sarny district, formerly Rokytne district) and the western districts of Zhytomyr region (Korosten' and Zviahel administrative districts) (Orlov & Yakushenko, 2017; iNaturalist).

The study area is located in the central part of the subrange of *R. luteum* in the Ukrainian Polissia. This species is known for forming dense undergrowth in pine, oak-pine, oak, alder, and secondary birch forests. In these habitats, *R. luteum* creates undergrowth with a canopy closure of 0.7–1.0, significantly influencing forestry management practices. Forest classification recognizes specific forest types: moist fairly infertile oak-pine site type with yellow azalea (in edaphotope B_3), which is the most widespread, and moist fairly fertile oak-pine site type with yellow azalea (in edaphotope C_3), which occurs less frequently. It is noteworthy that the associations *Pinetum rhododendrosum (lutei)* and *Querceto-Pinetum rhododendrosum (lutei)* are included in the Green Book of Ukraine (Ustymenko, 2009). Additionally, *R. luteum* is listed in Resolution 4 of the Bern Convention (Convention on the Conservation…, 1979; Interpretation Manual…, 2015). Thus, the species is considered rare and protected in both Europe and Ukraine, making forests containing it subject to special attention and conservation efforts.

Forest communities with dominance of *R. luteum* in the undergrowth occupy a significant area in the study region – approximately 62.000 ha (1983). Unfortunately, more recent data are unavailable. It should be noted that intensive forestry is conducted in the region, with main clear-cutting remaining the primary method for harvesting mature forests. During these operations, the tree stands and almost the entire understory are felled. Therefore, assessing the regeneration of *R. luteum* undergrowth following such logging is of significant interest and practical importance.

This study pursued the following goals: (1) to characterize forest communities with a predominance of *R. luteum* in the understory in mature, parent forests within the edaphotope of moist fairly infertile oak-pine site type (B_3) based on field research; (2) to study the regeneration dynamics of the *R. luteum* undergrowth in forest plantations of different ages (1–65 years) following main clear-cuttings of mature forests, including the assessment of canopy closure and vitality; (3) assess the success of *R. luteum*

undergrowth regeneration after clear-cutting in the B_3 edaphotope; (4) analyze the long-term dynamics of forest areas with *R. luteum* undergrowth in the most common forest site type (B_3).

General distribution and ecological characteristics of the yellow azalea in the Ukrainian Polissia. Forests with an understory dominated by the yellow azalea *(Rhododendron luteum* Sweet) have long attracted significant attention from researchers in Ukraine due to their relict status, disjunct range, and local distribution (Barbarych, 1962). In extensive forested areas of the Zhytomyr Ukrainian Polissia, this species dominates the undergrowth layer. According to A. I. Barbarych (1953), the area of forests containing *R. luteum* in the region was approximately 130.000 ha, while later estimates by A. S. Kozyakov and S. N. Kozyakov (1973) reported 55.000 ha, and more recent data by O. O. Orlov and D. M. Yakushenko (2017) indicated an area of 62.000 ha.

We analyzed literary sources on the cenotic conditions of the yellow azalea in the Ukrainian Polissia. Earlier studies suggested that the species was primarily confined to sphagnum peat bogs (Zerov, 1938), but this conclusion was later refuted by numerous studies (Barbarych, 1953; Povarnitsin, 1959; Kozyakov & Kozyakov, 1973, etc.). Within the pine forests of the Ukrainian Polissia, the association *Pinetum rhododendrosum* has been described under the classification by dominance (Povarnitsin, 1959). V. O. Povarnitsin noted that in the herb–dwarf-shrub layer of this community, *Vaccinium myrtillus* L. dominates, while the moss layer is dominated by *Pleurozium schreberi* (Willd. ex Brid.) Mitt. Typically, the *R. luteum* understory has a significant canopy closure of 0.7–0.8, and its height ranges from 1.5 to 2.0 meters.

A. I. Barbarych (1955) identified the association *Querceto-Pinetum herboso-myrtillosum* within the *Querceto-Pineta pteridioso-myrtillosa* group in Zhytomyr Polissia and described its genetic successor, *Querceto-Pinetum rhododendrosum* (*lutei*), which is characterized by the absence of a moss layer. Several researchers (Povarnitsin, 1971; Kozyakov & Kozyakov, 1973; Bradis & Andrienko, 1974; Myakushko, 1978) considered *Querceto-Pinetum rhododendroso-myrtillosum* and *Pinetum rhododendrosum nudum* to be the most typical associations that include *R. luteum* in the Ukrainian Polissia. These communities are distinguished by dense crown closure (up to 0.7–0.8, sometimes 1.0) of *R. luteum* undergrowth and the dominance of *Vaccinium myrtillus* in herb–dwarf-shrub layer. These researchers highlighted the high ecological plasticity of *R. luteum*, particularly regarding soil richness, as its ecological range spans three trophic site types, namely the infertile pine site type (A), the fairly infertile pine site type (B), and the fairly fertile [usually hardwood] site type (C). This species also exhibits adaptability to light availability, occurring both in open areas (forest edges, clearings) and in dense stands with tree canopy closure up to 0.8–1.0. The findings indicate that soil moisture is the primary limiting factor for the formation of dense *R. luteum* undergrowth.

According to the classification by dominance in the “Green Book of Ukraine” (2009), there are two main association groups that include *R. luteum* understory (Ustymenko, 2009), namely *Pineta* (*sylvestris*) *rhododendrosa* (*lutei*) and *Querceto* (*roboris*)-*Pineta* (*sylvestris*) *rhododendrosa llutei*), which comprise 10 distinct associations. The researcher noted that “The regeneration potential is satisfactory” (*op cit*., p. 106).

Over the past 25 years, a floristic classification of communities with *R. luteum* undergrowth was conducted using the Braun-Blanquet method, detailing their key ecological characteristics (Orlov *et al.*, 2000). The study revealed that in the moist fairly

infertile pine site type (B_3), the dominant association is *Molinio-Pinetum* J. Mat. (1973) 1981, specifically the *Molinio-Pinetum* var. *rhododendron luteum* variant, whereas in the moist fairly fertile [usually hardwood] site type (C_3), the dominant association is *Serratulo-Pinetum* J. Mat. 1981, specifically the *Serratulo-Pinetum* var. *rhododendron luteum* variant. The findings suggest that these variants do not contain specific diagnostic species, but *R. luteum* forms the densest undergrowth in B_3 and certain areas of C_3 site types, with a canopy closure of 0.8–1.0.

Analysis of the cenotic range of *R. luteum* revealed its distribution in the Zhytomyr Polissia (Orlov & Yakushenko, 2017). The largest and densest communities were found in the Korosten' administrative district (the former Yemilchyne and Olevsk districts) of Zhytomyr region. The researchers conclude that the yellow azalea "regenerates satisfactorily in clear-cut areas, especially after winter logging" (*op cit*., p. 96), emphasizing that "*R. luteum* is a violent species, demonstrating high vitality and a fully satisfactory regeneration potential" (*op cit*., p. 97). For the protection of forests with *R. luteum* undergrowth in Ukraine, two Important Plant Areas have been designated: "Emilchynski Lisy" and "Olevski Lisy" (Onyshchenko, 2017).

MATERIALS AND METHODS

The boundaries of the Zhytomyr Polissya were determined according to the current physico-geographical zoning of Ukraine (Marynych *et al*., 2007). The distribution of *R. luteum* was assessed based on herbarium collections from: the Herbarium of M. G. Kholodny Institute of Botany, NAS of Ukraine (KW), Herbarium of M. M. Gryshko National Botanical Garden, NAS of Ukraine (KWHA), Herbarium of Taras Shevchenko National University of Kyiv (KWU), Zhytomyr region museum of local lore (ZHM). Additionally, data were sourced from floristic databases iNaturalist (iNaturalist, 2025) and UkrBin (UkrBin, 2023), standard forest enterprise taxation descriptions, and our own field observations during 2000–2025.

The primary sources of data on the regeneration of *R. luteum* undergrowth were field observations conducted in 2025 in the Korosten' district of Zhytomyr region, particularly in Branch "Emil'chynske Forestry" and Branch "Luhynske Forestry" of the State Enterprise "Forests of Ukraine" as well as Emil'chynske Forestry of the municipal enterprise "Zhytomyroblagrolis". The map of location of experimental plots in the forest communities with undergrowth of *Rhododendron luteum* in the edaphotope of moist fairly infertile pine site type (B_3) is shown in **Fig. 1.**

The plots under study encompassed several age groups of forest communities including mature parent forests, aged 97–107 years, clear-cut areas, and forest plantations of the following types: younger age (pre-canopy closure), aged 1 year and 4–7 years; post-canopy closure, aged 8–16 years, 21–26 years, 31–34 years, 38–48 years, 51–52 years, and 58–65 years. In each age group, from 3 to 20 plots were investigated. On the experimantal plots, the following parameters were assessed: regeneration of the tree stand; regeneration of the *R. luteum* in the understory (canopy projective percentage, vitality, uniformity of distribution), the overall degree of forest community recovery with yellow azalea in the understory. Based on the analysis of spatial and temporal series of forest vegetation with *R. luteum* following main clear-cutting, the study determined the impact of logging on the extent and speed of this species' understory recovery and the feasibility of sustainable use of forest stands with *R. luteum* in the understory, including the possibility of conducting clear-cutting in such forests.

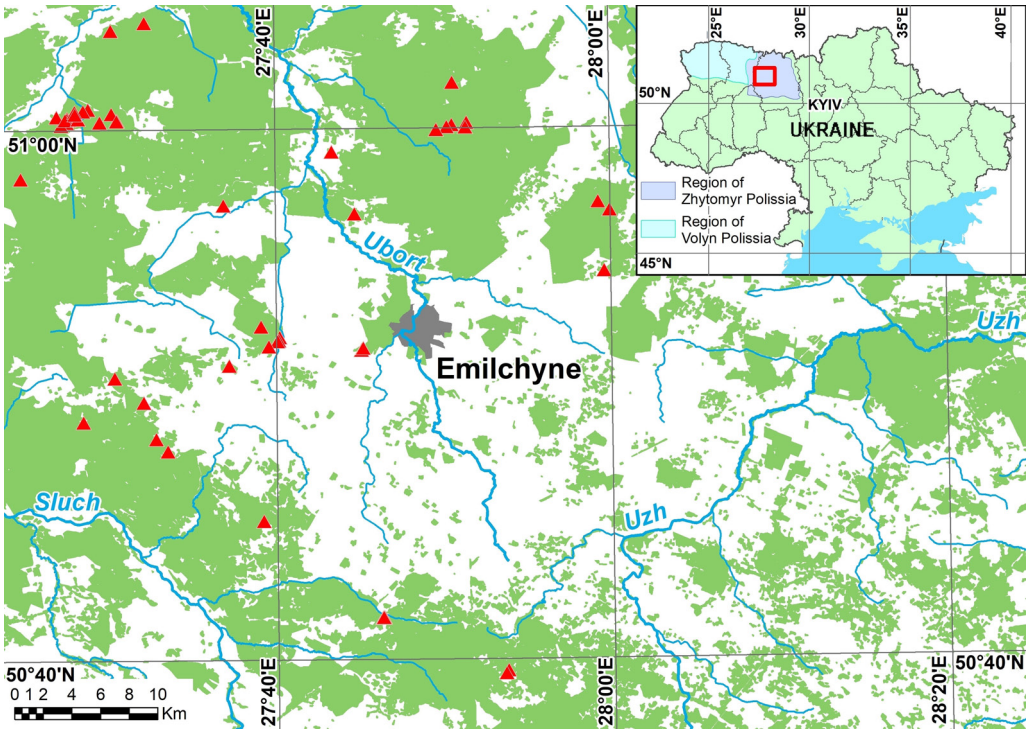

Fig. 1. The map of location of experimental plots in the forest ecosystems with *Rhododendron luteum* undergrowth in the edaphotope of moist fairly infertile pine site type (B_3) in Zhytomyr Polissia

The long-term dynamics of *R. luteum* understory area was studied based on standard taxation descriptions of the Branch "Luhynske Forestry" of the SE "Forests of Ukraine" for the period of 1978–2018.

Statistical data processing was carried out using standard methods of variation statistics (Horkavyi, 2009). The calculation of arithmetic means and their errors, as well as the construction of diagrams, was performed using Excel software.

RESULTS AND DISCUSSION

The generalization of data from experimental plots allowed for the identification of *Rhododendron luteum* understory regeneration patterns following main clear-cutting of mature stands in the edaphotope of moist fairly infertile pine site type (B_3) within the study region (see **Table**).

The data in **Table** reveal significant regularities. Notably, in mature parent Scots pine forests aged 97–107 years, the *R. luteum* understory was in a good state (**Fig. 2**). It had a canopy closure of 0.8–0.9 (up to 1.0), was uniformely distributed, reached a height of 1.8–2.5 m, and exhibited vigorous flowering and fruiting.

After main clear-cutting in edaphotope B_3, new forest plantations are typically established, consisting of Scots pine (*Pinus sylvestris* L.) alone or Scots pine with silver birch (*Betula pendula* Roth), Scots pine with pedunculare oak (*Quercus robur* L.), etc. For this, furrows are plowed, and seedlings are planted at a spacing of 2.5×0.7 m, with various species mixing schemes. As a result, the plantation area consists of alternating furrows (rows) and wide inter-row spaces (2.5–3 m wide).

Regeneration of *Rhododendron luteum* in areas after clear-cutting of main use and creation of forest plantations in the edaphotope of moist fairly infertile pine site type (B_3)

Branch of SE "Forests of Ukraine" or "Zhytomyroblagrolis", forestry, No quartier / section	Year of clear cutting	Plantation age, years	Planting scheme, m	Composition of the forest stand	Condition of *R. luteum* undergrowth, canopy closure, distribution
1	2	3	4	5	6
BEF, Hartivske, 67/8	–	97	–	70 % – Scots pine, 30 % – silver birch	Good, closure 0.8–0.9, uniform distribution
BEF, Kochychynske, 1/26	–	97	–	80 % – Scots pine, 20 % – silver birch	Good, closure 0.8–0.9, uniform distribution
BEF, Kochychynske, 2/23	–	107	–	80 % – Scots pine, 20 % – silver birch	Good, closure 0.9–1.0, uniform distribution
BEF, Hlumchanske, 4/6	–	107	–	90 % – Scots pine, 10 % – silver birch	Good, closure 0.9–1.0, uniform distribution
BEF, Korolivske, 26/36	2024	1	2.5×0.7	80 % – Scots pine, 20 % – silver birch	Satisfactory, closure 0.10–0.20, inter-row distribution
BEF, Korolivske, 31/21	2023	1	2.5×0.7	80 % – pedunculare oak, 20 % – silver birch	Satisfactory, closure 0.10–0.15, inter-row distribution
BEF, Kochychynske, 25/36	2023	1	2.5×0.7	80 % – Scots pine, 20 % – silver birch	– ” –
EFZ, Barashivske, 92/50	2023	1	2.5×0.7	60 % – Scots pine, 40 % – pedunculare oak	– ” –
BEF, Hartivske, 66/13	2022	2	3.0×0.5	80 % – Scots pine, 20 % – red oak	Satisfactory, closure 0.15–0.20, inter-row distribution
BEF, Kochychynske, 35/45	2023	2	2.5×0.7	80 % – Scots pine, 20 % – silver birch	– ” –
BEF, Kochychynske, 34/31	2020	3	2.5×0.7	80 % – Scots pine, 20 % – silver birch	– ” –
BEF, Hartivske, 66/15	2020	4	3.0×0.5	80 % – Scots pine, 20 % – pedunculare oak	– ” –

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1	2	3	4	5	6
BEF, Kochychynske, 31/21	2016	8	2.5×0.7	100 % – Scots pine	Satisfactory, closure 0.15–0.25, uniform distribution
BEF, Zhuzhelske, 62/25	2013	11	–	60 % – silver birch, 40 % – aspen	Satisfactory, closure 0.15–0.20, clumped distribution
BEF, Hartivske, 67/20	2012	12	–	100 % – Scots pine	– ” –
BEF, Kochychynske, 31/31	2010	14	3.0×0.5	100 % – Scots pine	Satisfactory, closure 0.15–0.25, uniform distribution
EFZ, Serbivske, 117/7	2010	16	–	80 % – silver birch, 20 % – Scots pine	Satisfactory, closure 0.20–0.25, clumped distribution
EFZ, Emil’chynske, 58/43	2010	16	–	40 % – Scots pine, 60 % – silver birch	– ” –
BEF, Hartivske, 65/28	2008	16	2.5×0.7	100 % – Scots pine	Satisfactory, closure: 0.25–0.30, uniform distribution
EFZ, Serbivske, 50/30	2003	21	–	70 % – silver birch, 30 % – Scots pine	Satisfactory, closure: 0.20–0.30, clumped distribution
EFZ, Serbivske, 117/8	2003	21	–	80 % – silver birch, 20 % – Scots pine	Satisfactory, closure 0.30–0.40, clumped distribution
BEF, Kochychynske, 32/13	2000	25	3.0×0.5	40 % – Scots pine, 60 % – silver birch	Satisfactory, closure 0.20–0.25, uniform distribution
BEF, Kochychynske, 31/41	1998	26	–	80 % – silver birch, 20 % – Scots pine	– ” –
BEF, Kochychynske, 34/5	1998	26	3.0×0.5	50 % – Scots pine, 50 % – silver birch	Satisfactory, closure 0.25–0.30, uniform distribution
EFZ, Serbivske, 31/23	1993	31	3.0×0.5	60 % – Scots pine, 40 % – silver birch	Good, closure 0.30–0.40, uniform distribution
BEF, Kochychynske, 31/9	1991	33	–	50 % – alder, 30% – silver birch, 20 % – Scots pine	Good, closure 0.20–0.25, clumped distribution
BEF, Kochychynske, 32/14	1990	34	3.0×0.5	90 % – Scots pine, 10 % – silver birch	Satisfactory, closure 0.25–0.30, uniform distribution

End of the Table

1	2	3	4	5	6
BEF, Kochychynske, 35/46	1986	38	3.0×0.5	90 % – Scots pine, 10 % – silver birch	Satisfactory, closure 0.35–0.40, uniform distribution
EFZ, Emil'chynske, 104/37	1983	41	2.5×0.7	100 % – Scots pine + silver birch	Good, closure 0.40–0.50, uniform distribution
EFZ, Emil'chynske, 104/15	1982	42	3.0×0.5	100 % – Scots pine	– " –
BEF, Kochychynske, 31/37	1978	46	2.5×0.7	80 % – Scots pine, 20 % – silver birch	Good, closure 0.35–0.40, uniform distribution
BEF, Kochychynske, 31/37.1	1977	47	2.5×0.7	80 % – Scots pine, 20 % – silver birch	Good, closure 0.37–0.45, uniform distribution
BEF, Kochychynske, 31/37.2	1976	48	2.5×0.7	80 % – Scots pine, 20 % – silver birch	Good, closure 0.40–0.50, uniform distribution
EFZ, Emil'chynske, 75/12	1973	51	–	80 % – Scots pine, 10 % – pedunculare oak, 10 % – aspen	Good, closure 0.60–0.70, uniform distribution
EFZ, Serbivske, 25/18	1973	51	2.5×0.7	70 % – Scots pine, 20 % – aspen, 10 % – silver birch	Good, closure 0.60–0.70, uniform distribution
EFZ, Emil'chynske, 98/18	1972	52	–	80 % – Scots pine, 10 % – silver birch, 10 % – pedunculare oak	Good, closure 0.65–0.75, uniform distribution
BEF, Kochychynske, 25/42	1966	58	2.5×0.7	100 % – Scots pine + silver birch	Good, closure 0.65–0.80, uniform distribution
EFZ, Emil'chynske, 64/9	1963	61	–	100 % – Scots pine + silver birch	Good, closure 0.70–0.80, uniform distribution
EFZ, Serbivske, 85/17	1963	61	–	100 % – Scots pine + silver birch	Good, closure 0.70–0.80, uniform distribution
BEF, Kochychynske, 32/19	1959	65	2.5×0.7	70 % – Scots pine, 30 % – silver birch	Good, closure 0.75–0.85, uniform distribution

Note: BEF – Branch "Emil'chynske Forestry" of the State Enterprise "Forests of Ukraine"; EFZ – Emil'chynske Forestry of the municipal enterprise "Zhytomyroblagrolis"

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Fig. 2. A continuous undergrowth of *Rhododendron luteum* (0.9-1.0 closure) in a mature pine forest aged 107 years (Hlumchanske forestry, quartier 4, section 6)

In 1-year-old forest plantations, the condition of the *R. luteum* understory was satisfactory. The species flowered and fruited well **(Fig. 3**), was mostly preserved in the inter-rows, and had a total projective cover of 0.10–0.15. Also, massive shoot regeneration from roots was observed. By the age of 2–4 years, the projective cover of *R. luteum* slightly increased to 17–20 %.

Fig. 3. The remains of *Rhododendron luteum* undergrowth on the current year's clear-cut plot prepared for the establishment of pine forest plantation (Kochychynske forestry, quartier 25, section 36)

After crown closure in young stands aged 8–16 years, the condition of the *Rhododendron luteum* undergrowth was satisfactory. Its projective cover gradually increased to 20–25(30) %**,** and the species flowered and fruited well (**Fig. 4**). However, a limiting factor for its development was the high crown density of the young tree stand, which sometimes reached 0.8–1.0. The *R. luteum* shrubs were mainly located in gaps, typically displaying an uneven, clumped distribution, with only about half of the plants flowering. Notably, the most significant suppression of *R. luteum* occurred in dense young stands that developed as a result of natural regeneration of tree species after logging, primarily those of *Betula pendula* Roth and *Populus tremula* L. This age stage is considered critical for the preservation and regeneration of *R. luteum*. Therefore, to support the species' development in such stands, it is essential to conduct timely and adequately intense thinning operations.

Fig. 4. An undergrowth of *Rhododendron luteum* with 30 % projective cover in a 12-year-old plantation of Scots pine (Hartivske forestry, quartier 67, section 20)

In the 21–26-year-old age group**,** the *R. luteum* undergrowth was in a satisfactory condition**.** The formation of this layer continued, with canopy closure slowly increasing to 25–30%**,** and its initially clumped distribution gradually transforming into a more uniform pattern. Flowering was observed in 70–75% of the shrubs**.**

In the 31–34-year-old age group**,** the condition of the *R. luteum* understory remained satisfactory, and its formation continued. The layer projective cover ranged from 20 to 40%, and the distribution was uniform. With increasing stand age, in the 38–48-year-old age group, the condition of the *R. luteum* understory improved, with projective cover increasing to 40–50%. The species flowered and fruited well, and it was evenly distributed across the area.

As stand age further increased to 58–65 years, the projective cover of *R. luteum* reached 65–85 %, demonstarting a uniform distribution. At this stage, the species reached a quasi-equilibrium state within the forest communities, forming a distinct lower layer of the phytocoenosis. Physiognomically, these communities were nearly indistinguishable from the mature parent stands (**Fig. 5**).

Fig. 5. An undergrowth of *Rhododendron luteum* with 85 % projective cover in a 58-year-old plantation of Scots pine (Kochychynske forestry, quartier 25, section 42)

The generalization of data on the regeneration of the *Rhododendron luteum* undergrowth following clear-cutting – as indicated by its projective cover – allowed for the construction of **Fig. 6**.

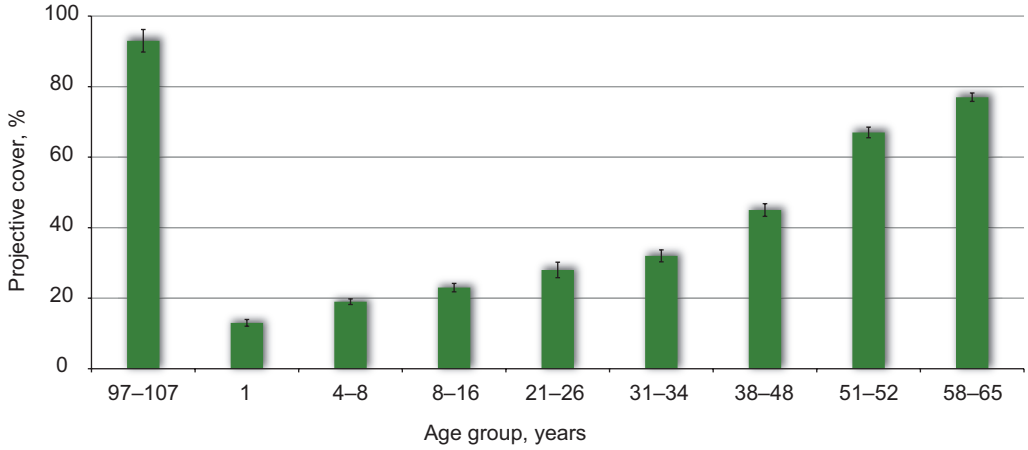

Fig. 6. The dynamics of the projective cover of *Rhododendron luteum* undergrowth in forest plantations established after main clear-cutting in the moist fairly infertile pine site type (B_3)

An analysis of data presented in **Fig. 6** leads to the conclusion that in mature parent communities of pine forests, aged 97–107 years, with an understory of *R. luteum* in the

edaphotope of moist, fairly infertile pine site type (B_3), the average undergrowth projective cover of this species was 93±3.2 %. However, after clear-cutting and the establishment of forest plantations, this value sharply decreased to 13±1.0 %. Subsequently, as the plantations aged, this indicator increased gradually from 19±0.8 % in the 2–4-year-old age group to 77±1.2 % in the 58–65-year-old age group. It seems reasonable to conclude that in most pine forests plots with an *R. luteum* undergrowth within the edaphotope of moist, fairly infertile pine site type (B_3), this understory successfully regenerates after clear-cutting and plantation establishment, given current logging and forest management practices.

However, a survey of over 130 sites, including forest plantations and areas left for natural regeneration in this edaphotope, revealed that in 85 % of the studied plots, *R. luteum* regeneration was satisfactory, while in 15 % of the plots, it was absent. This lack of regeneration was primarily due to untimely or insufficient thinning operations, leading to the formation of overly dense tree stands that suppressed the development of the *R. luteum* understory.

An analysis of the long-term dynamics of forest communities dominated by *Rhododendron luteum* in the understory is of significant interest. Based on standard taxation descriptions from Branch “Luhynske Forestry” of SE “Forests of Ukraine”, covering five revision periods over 40 years (1978–2018), this dynamic was identified in the most widespread edaphotope for the species in the study region – moist, fairly infertile pine site type (B_3) (**Fig. 7**).

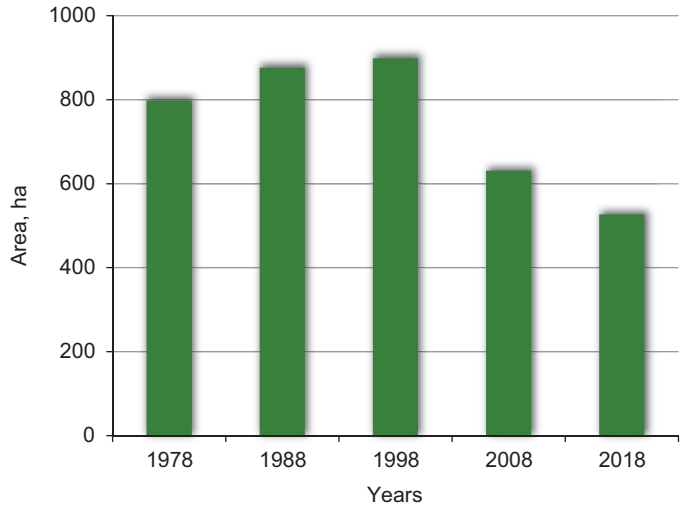

Fig. 7. The long-term dynamics of forest communities with *Rhododendron luteum* dominance in the undergrowth in the edaphotope of moist fairly infertile pine site type (B_3) in the Branch “Luhynske forestry” of the State Enterprise “Forests of Ukraine” (1978–2018)

The results of the analysis of the long-term dynamics of forest areas dominated by *Rhododendron luteum* in the understory (**Fig. 7**) indicate that in the Branch “Luhynske forestry” of SE “Forests of Ukraine”, within the main site type for the species **–** moist fairly infertile pine site type (B_3) **–** the area of forests communities dominated by *R. luteum* in the understory significantly decreased from 798 ha in 1978 to 527.2 ha in 2018, showing a 1.5-fold reduction.

In our opinion, the reasons for this decline in forests *R. luteum* understory within the studied site type are complex, including:

1) subjective reasons, related to forest management quality, particularly the delineation of the moist fairly infertile pine site type with yellow azalea as distinct from the general moist fairly infertile pine site type (B_3);
2) objective reasons, such as the absence of *R. luteum* regeneration in some clear-cut areas (approximately 15 % of sites, according to our data) and climate change in the region since 2000, specifically warming and increased aridity (Didukh, 2023). The latter factor is of particular importance, because, as previous studies (Orlov *et al.*, 2000) demonstrated, soil moisture is the primary limiting factor for the formation of an *R. luteum* understory.

CONCLUSION

1. Most studies on *R. luteum* conducted before 2000 primarily focused on its specific distribution in the Ukrainian Polissia, its relict status, and medicinal raw material stocks. Publications addressing ecological, phytocoenotic, and silvicultural significance of the species are scarce and fragmented. The long-term dynamics of *R. luteum* understory distribution in the Ukrainian Polissia remained completely understudied.
2. In mature parent pine forests aged 97–107 years, the conditions of the *R. luteum* understory were good, with a canopy closure of 0.8–0.9 (up to 1.0) and a uniform distribution. After clear-cutting in the B_3 site type, the conditions of the *R. luteum* understory in 1-year-old plantations were satisfactory, the species was mostly preserved in inter-rows, with a projective cover of 0.10–0.15. In 2–4-year-old plantations, this cover slightly increased to 17–20 %, and in the 8–16-year-old group, it reached 20–25(30) %**.** The main limiting factor for its development was the high degree of crown closure of the young tree stand.
3. In 21–26-year-old plantations**,** the understory condition remained satisfactory, with continuing formation of this layer and a gradual increase in projective cover to 25–30 %. The distribution transitioned from a clumped to uniform pattern. As the plantations aged, the projective cover gradually increased to 65–85 %, and the species reached a quasi-equilibrium state in forest communities, forming a specific microhabitat in the lower phytocenotic layers. Physiognomically, these communities were nearly indistinguishable from the parent stands.
4. The understory of *R. luteum* did not regenerate on about 15 % of sites following clear-cutting.
5. From 1978 to 2018, in the Branch “Luhynske Forestry” of SE “Forests of Ukraine”, the area of forests dominated by *R. luteum* in understory in moist fairly infertile pine site type (B_3) significantly decreased from 798 ha in 1978 to 527.2 ha in 2018, a 1.5-fold reduction.
6. The causes of this decline are complex and include (1) subjective factors, related to forest management quality, particularly the delineation of the moist fairly infertile pine site type with yellow azalea as distinct from the general moist fairly infertile pine site type (B_3); (2) objective factors associated with the absence of *R. luteum* regeneration in some clear-cut areas and climate change in the region since 2000, specifically warming and increased aridity.
7. When establishing forest plantations using a 2.5×0.7 planting scheme, *R. luteum* regenerates well in the interrows but it may surpress seedlings in the rows.

Maintenance interventions are recommended in young plantations with mowing *R. luteum* shrubs within 2-meter-wide corridors (1 m on each side of the row).

A key limiting factor for *R. luteum* population regeneration in young stands is excessive tree density (a combination of planted trees and natural regeneration of birch and aspen). To support *R. luteum* understory regeneration, we recommend to conduct intermediate cuttings in young tree canopies.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: the authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Animal Rights: this article does not contain any studies with animal subjects performed by any of the authors.

AUTHOR CONTRIBUTIONS

Conceptualization, [O.O.]; methodology, [A.T.; O.O.; O.Zh.]; validation, [O.O.; A.T.; O.Zh.]; formal analysis, [A.T.; O.O.; O.Zh.]; investigation, [A. T.; O.O.; O.Zh.]; resources, [A.T.; O.O.; O.Zh.]; data curation, [A.T.; O.O.; O.Zh.]; writing – original draft preparation, [A.T.; O.O.; O.Zh.]; writing – review and editing, [O.O.; O.Zh.]; visualization, [O.Zh.], supervision, [A.T.; O.O.; O.Zh.]; project administration, [O.O.]; funding acquisition, [-].

All authors have read and agreed to the published version of the manuscript.

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ВІДНОВЛЕННЯ ПІДЛІСКУ *RHODODENDRON LUTEUM* SWEET (ERICACEAE) ПІСЛЯ СУЦІЛЬНИХ РУБОК ГОЛОВНОГО КОРИСТУВАННЯ В УКРАЇНСЬКОМУ ПОЛІССІ

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Вступ. Рододендрон жовтий (*Rhododendron luteum* Sweet) – реліктовий вид, фрагментарно поширений в Україні переважно у Житомирському Поліссі на площі близько 62 тис. га. Центральна частина субареалу виду розташована у Коростенському районі Житомирської області, де у лісах в едафотопах вологий субір (B_3) та вологий сугруд (C_3) він створює підлісок зі зімкнутістю 0,8–0,9(1,0). Ці лісові угруповання є рідкісними, їх занесено до "Зеленої книги України" (2009), вид також включено до Бернської конвенції (Convention…, 1979). Виключити такі значні площі лісів з лісокористування є недоцільним, однак варто проаналізувати вплив лісокористування на популяцію виду – щоб оцінити можливості експлуатації лісів з підліском рододендрона жовтого.

Метою цього дослідження було: 1. На основі польових досліджень схарактеризувати в едафотопі вологий субір (B_3) ценози з переважанням *R. luteum* у підліску в материнських, стиглих лісах; 2. Вивчити динаміку відновлення підліску *R. luteum* у лісових культурах різного віку (1–65 років) після проведення суцільних рубок головного користування, зімкнутість і життєвість виду; 3. Оцінити успішність відновлення підліску *R. luteum* після проведення їх в едафотопі (B_3); 4. Проаналізувати багаторічну динаміку площ лісів з підліском з цього виду в едафотопі вологий субір (B_3).

Матеріали і методи. Поширення *R. luteum* оцінено на основі гербарних колекцій: Національного гербарію Інституту ботаніки ім. М. Г. Холодного, НАН України (KW), гербарію Національного ботанічного саду ім. М. М. Гришка, НАН України (KWHA), гербарію Київського Національного університету ім. Тараса Шевченка (KWU); флористичних баз даних iNaturalist and UkrBin, стандартних таксаційних описів лісогосподарських підприємств; а також власних польових досліджень 2000–2025 рр.

Головними джерелами даних щодо відновлення підліску з *R. luteum* були власні польові спостереження, проведені у 2025 р. в Коростенському адміністративному районі Житомирської області – у філіях "Ємільчинське лісове господарство" та "Лугинське лісове господарство" ДП "Ліси України"; ДП "Ємільчинське лісове господарство" комунального агролісогосподарського підприємства "Житомироблагроліс". Багаторічну динаміку площ підліску *R. luteum* вивчено на основі стандартних таксаційних описів філії "Лугинське лісове господарство" ДП "Ліси

України” за період 1978–2018 рр. Статистичну обробку даних проведено загальноприйнятими методами варіаційної статистики (Горкавий, 2009). Розрахунок середніх арифметичних значень і їхніх похибок, а також побудова діаграм здійснена зі застосуванням пакету Excel.

Результати й обговорення. У стиглих материнських соснових лісах віком 97–107 років стан підліску *R. luteum* був хорошим, він мав зімкнутість 0,8–0,9 (до 1,0), розміщення було рівномірним. Після проведення суцільної рубки головного користування в едафотопі B_3, у лісових культурах віком 1 рік стан підліску *R. luteum* був задовільним, він зберігався переважно у міжряддях, його проєктивне покриття становило 10–15 %. У віці лісових культур 2–4 роки проєктивне покриття виду незначно збільшилося – до 17–20 %, а у віковій групі 8–16 років – до 20–25(30) %. Лімітуючим чинником його розвитку була значна зімкнутість крон молодого деревостану разом із природним поновленням деревних порід. У віковій групі 21–26 років стан підліску *R. luteum* був задовільним, формування цього ярусу тривало, його зімкнутість повільно збільшувалася до 25–30 %, а розміщення з куртинного трансформувалось у рівномірне. У разі збільшення віку насаджень до 65-річного віку проєктивне покриття виду поступово зросло до 65–85 %, за рівномірного розміщення. Вид у 60–65 культурах досяг квазірівноваги, формував специфічне середовище у нижніх ярусах фітоценозів. Фізіономічно ці угруповання майже не відрізнялися від материнських. У філії “Лугинське лісове господарство” ДП “Ліси України” у найпоширенішому едафотопі *R. luteum* у регіоні – вологий субір (B_3) площа лісів з підліском цього виду протягом 1978–2018 рр. значно зменшилася – з 798 га у 1978 р. до 527,2 га у 2018 р.

Висновки. На більшості ділянок після суцільних рубок головного користування та створення лісових культур у віці близько 40 років відбувається відновлення більшменш зімкнутого підліску *R. luteum*, який у віці насаджень 60–65 років досягає квазірівноваги. На частині ділянок – близько 15 % від обстежених, – після проведення суцільних рубок головного користування підлісок *R. luteum* не відновлюється. Протягом 1978–2018 рр. площі *R. luteum* в едафотопі B_3 у філії “Лугинське лісове господарство” ДП “Ліси України” значно зменшилися. В едафотопі вологий субір (B_3) площа лісів з підліском *R. luteum* зменшилася з 798 га у 1978 р. до 527,2 га у 2018 р. – у 1,5 рази. Під час створення лісових культур за схемою 2,5×0,7 м рододендрон жовтий задовільно поновлюється у міжряддях, однак з боків може заглушати саджанці у рядах. Рекомендуємо проводити догляд за лісовими культурами молодшого віку у коридорах шириною 2 м (по 1 м в обидва боки від ряду), з викошуванням у них кущів *R. luteum*. Лімітуючим чинником відновлення популяції *R. luteum* у молодняках є значна загущеність молодого деревостану (разом лісових культур і природного поновлення *Betula pendula* Roth та *Populus tremula* L.). Тому з метою сприяння відновленню підліску рододендрона жовтого рекомендуємо вчасно проводити рубки догляду, зокрема, освітлення, а у більш пізньому віці – прочищення.

Ключові слова: рододендрон жовтий (*Rhododendron luteum* Sweet), лісові культури, підлісок, проєктивне покриття, едафотоп, вологий субір (B_3)

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APPENDIX 1

Experimental plots in sites after clear cuttings of the main use in the forests with undergrowth of *Rhododendron luteum* and forest plantations of different age in the edaphotope of moist fairly infertile oak-pine site type (B_3) in Emilchinske Forestry Branch of the State Enterprise "Forests of Ukraine"

Branch of State Enterprise "Forests of Ukraine", forestry, No quartier / section	Year of clear cutting	Age, years	Planting scheme, m	Composition of the forest stand	Geographical coordinates
1	2	3	4	5	6
BEF, Hartivske, 29/27	–	97	–	80 % – Scots pine, 20 % – silver birch	51°01′43.0″N 27°50′37.7″E
BEF, Hartivske, 67/8	–	97	–	70 % – Scots pine, 30 % – silver birch	51°00′12.7″N 27°51′28.3″E
BEF, Kochychynske, 1/26	–	97	–	80 % – Scots pine, 20 % – silver birch	51°03′44.9″N 27°30′14.2″E
BEF, Kochychynske, 2/23	–	107	–	80 % – Scots pine, 20 % – silver birch	51°04′02.6″N 27°32′14.3″E
BEF, Hlumchanske, 4/6	–	107	–	90 % – Scots pine, 10 % – silver birch	50°58′10.9″N 27°24′49.0″E
BEF, Korolivske, 26/36	2024	1	2.5×0.7	80 % – Scots pine, 20 % – silver birch	50°57′11.4″N 27°59′16.9″E
BEF, Korolivske, 31/21	2023	1	2.5×0.7	80 % – pedunculare oak, 20 % – silver birch	50°56′52.4″N 27°59′58.6″E
BEF, Kochychynske, 25/36	2023	1	2.5×0.7	80 % – Scots pine, 20 % – silver birch	51°00′47.5″N 27°28′51.7″E
BEF, Hartivske, 66/13	2022	2	3.0×0.5	80 % – Scots pine, 20 % – red oak	51°00′07.6″N 27°50′35.8″E
BEF, Kochychynske, 35/45	2023	2	2.5×0.7	60 % – Scots pine, 40 % – silver birch	51°00′22.4″N 27°30′34.4″E
BEF, Kochychynske, 34/31	2020	3	2.5×0.7	80 % – Scots pine, 20 % – silver birch	51°00′18.0″N 27°29′33.4″E
BEF, Hartivske, 66/15	2020	4	3.0×0.5	80 % – Scots pine, 20 % – red oak	51°00′03.2″N 27°50′17.2″E
BEF, Kochychynske, 31/21	2016	8	2.5×0.7	100 % – Scots pine	51°00′23.6″N 27°27′41.7″E
BEF, Zhuzhelske, 62/25	2013	11	–	60 % – silver birch, 40 % – aspen	50°52′34.2″N 27°39′06.4″E
BEF, Hartivske, 67/20	2012	12	–	100 % – Scots pine	51°00′02.0″N 27°51′24.4″E

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End of the Appendix 1

1	2	3	4	5	6
BEF, Kochychynske, 31/31	2010	14	3.0×0.5	100 % – Scots pine	51°00′18.2″N 27°27′34.9″E
BEF, Hartivske, 65/28	2008	16	–	100 % – Scots pine	50°59′56.5″N 27°49′39.6″E
BEF, Kochychynske, 32/13	2000	25	3.0×0.5	40 % – Scots pine, 60 % – silver birch	51°00′31.7″N 27°28′03.0″E
BEF, Kochychynske, 31/41	1998	26	–	80 % – silver birch, 20 % – Scots pine	51°00′11.3″N 27°27′15.3″E
BEF, Kochychynske, 34/5	1998	26	3.0×0.5	50 % – Scots pine, 50 % – silver birch	51°00′37.0″N 27°30′15.2″E
BEF, Kochychynske, 31/9	1991	33	–	50 % – alder, 30 % – silver birch, 20 % – Scots pine	51°00′30.9″N 27°26′59.0″E
BEF, Kochychynske, 32/14	1990	34	3.0×0.5	90 % – Scots pine, 10 % – silver birch	51°00′30.0″N 27°28′07.8″E
BEF, Kochychynske, 35/46	1989	38	3.0×0.5	90 % – Scots pine, 10 % – silver birch	51°00′20.7″N 27°30′34.0″E
BEF, Kochychynske, 31/37	1978	46	2.5×0.7	80 % – Scots pine, 20 % – silver birch	51°00′28.1″N 27°27′36.3″E
BEF, Kochychynske, 31/37.1	1977	47	2.5×0.7	80 % – Scots pine, 20 % – silver birch	51°00′24.5″N 27°27′35.3″E
BEF, Kochychynske, 31/37.2	1976	48	2.5×0.7	80 % Scots pine, 20 % – silver birch	51°00′23.9″N 27°27′29.9″E
BEF, Kochychynske, 25/42	1966	58	2.0×0.5	100 % – Scots pine + silver birch	51°00′43.3″N 27°28′34.3″E
BEF, Kochychynske, 32/19	1959	65	2.5×0.5	70 % – Scots pine, 30 % – silver birch	51°00′25.9″N 27°28′16.4″E
BEF, Kochychynske, 24/67	1954	70	2.0×0.5	90 % – Scots pine, 10 % – silver birch	51°00′42.0″N 27°28′03.4″E
BEF, Kochychynske, 32/6	1952	72	3.0×0.7	100 % – Scots pine + silver birch	51°00′36.5″N 27°28′05.0″E

Note: BEF – Branch “Emil’chynske Forestry” of the State Enterprise “Forests of Ukraine”; EFZ – Emil’chynske Forestry of the municipal enterprise “Zhytomyroblagrolis”. Tree species: pedunculare oak (*Quercus robur* L.), aspen (*Populus tremula* L.); silver birch (*Betula pendula* Roth.), Scots pine (*Pinus sylvestris* L.), northern red oak (*Quercus rubra* L.)

APPENDIX 2

Brief characteristic of experimental plots in forest plantations of different age with undergrowth of *Rhododendron luteum* after clear cuttings of the main use in the edaphotope of moist fairly infertile oak-pine site type (B_3) in Emil'chinske Forestry of the municipal enterprise "Zhytomyroblagrolis"

Municipal enterprise "Zhytomyroblagrolis", forestry, No quartier /section	Age, years	Composition of the forest stand	Geographical coordinates
1	2	3	4
EFZ, Barashivske, 92/50	1	60 % – Scots pine, 40 % – pedunculare oak	50°39′34.6″N 27°53′39.4″E
EFZ, Barashivske, 94/20	5	70 % – silver birch, 10 % – aspen, 10 % – alder, 10 % – pedunculare oak	50°39′28.3″N 27°53′32.3″E
EFZ, Serbivske, 117/7	16	80 % – silver birch, 20 % – Scots pine	50°41′36.3″N 27°46′19.1″E
EFZ, Yemil'chynske, 58/43	16	40 % – Scots pine, 60 % – silver birch	50°59′08.7″N 27°43′24.1″E
EFZ, Serbivske, 50/30	21	70 % – silver birch, 30 % – Scots pine	50°49′44.5″N 27°32′05.5″E
EFZ, Serbivske, 117/8	21	80 % – silver birch, 20 % – Scots pine	50°41′35.3″N 27°46′13.8″E
EFZ, Serbivske, 55/17	26	70 % – silver birch, 20 % – Scots pine, 10 % – aspen	50°48′22.2″N 27°32′49.5″E
EFZ, Serbivske, 117/9	26	80 % – silver birch, 20 % – Scots pine	50°41′35.8″N 27°46′16.4″E
EFZ, Serbivske, 31/23	31	60 % – Scots pine, 40 % – silver birch	50°49′00.6″N 27°28′29.7″E
EFZ, Yemil'chynske, 104/37	41	100 % – Scots pine + silver birch	50°51′39.9″N 27°45′05.1″E
EFZ, Serbivske, 45/13	42	80 % – Scots pine, 20 % – aspen	50°51′07.0″N 27°37′11.7″E
EFZ, Yemil'chynske, 104/15	42	100 % – Scots pine	50°51′44.8″N 27°45′12.1″E
EFZ, Yemil'chynske, 98/5	46	100 % – Scots pine	50°52′10.1″N 27°40′13.5″E
EFZ, Yemil'chynske, 98/8	46	100 % – Scots pine	50°52′03.3″N 27°40′09.8″E

End of the Appendix 2

1	2	3	4
EFZ, Serbivske, 58/12	47	100 % – Scots pine	50°47′54.1″N 27°33′31.3″E
EFZ, Yemil'chynske, 98/13	48	100 % – Scots pine	50°52′01.4″N 27°40′06.0″E
EFZ, Yemil'chynske, 63/16	48	80 % – Scots pine, 20 % – silver birch	50°57′08.6″N 27°36′54.5″E
EFZ, Yemil'chynske, 75/12	51	80 % – Scots pine, 10 % – pedunculare oak, 10 % – aspen + silver birch	50°54′35.9″N 27°59′36.7″E
EFZ, Serbivske, 25/18	51	70 % – Scots pine, 20 % – aspen, 10 % – silver birch + pedunculare oak + alder	50°50′39.8″N 27°30′22.1″E
EFZ, Yemil'chynske, 98/18	52	80 % – Scots pine, 10 % – silver birch, 10 % – pedunculare oak + aspen	50°51′49.5″N 27°39′34.5″E
EFZ, Yemil'chynske, 64/9	61	100 % – Scots pine + silver birch	50°56′48.0″N 27°44′43.7″E
EFZ, Serbivske, 85/17	61	100 % – Scots pine + silver birch	50°45′15.4″N 27°39′11.7″E

Note: EFZ – Emil'chinske Forestry of the municipal enterprise "Zhytomyroblagrolis". Tree species: Scots pine (*Pinus sylvestris* L.), pedunculare oak (*Quercus robur* L.), aspen (*Populus tremula* L.); silver birch (*Betula pendula* Roth.)