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Current state and productivity of age-old experimental plantations of prof. V.D. Ogievsky in the northeastern part of Ukraine

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Abstract

This research is aimed at determining the health condition and productivity of Scots pine (*Pinus sylvestris* L.) stands created during 1906–1908 on the initiative of Prof. V. D. Ogievsky. The scheme of silvicultural experiments included: determining the influence of different widths and directions of clear felling on the natural regeneration, testing of pine plantations of pure and mixed composition and the choice of methods for their creation. In terms of health condition, 103–105-year-old artificial pine stands are weakened and their health condition is slightly worse compared to the aged pines of natural origin. The productivity of age-old linden-pine plantations is higher than of pure pine plantations, and the stock of stem wood in plantations created by seed sowing and marketability is higher compared to the plantations created by planting seedlings.

Key words

Scots pine, natural stands, forest plantations, productivity, health condition

Introduction

Growing and forming highly productive, biologically stable, valuable stands that perform high-quality water protection, soil protection and other useful functions is an urgent task for the sustainable development of forestry in Ukraine.

Unsatisfactory natural regeneration of Scots pine in the forests of Ukrainian Polissya in the early 60s of the 19th century led to the artificial restoration of clear-cuts. In the Chernihiv region in Sobytsky Forestry (now the state enterprise 'Shostkynske Forest Economy' [SE 'Shostkynske Forestry'] of Sumy region), the experimental forestry was managed by Prof. Vasyl Dmytrovych Ogievsky.

During 1897–1916, more than 300 research objects were created on his initiative. From the first years, some plots of forest plantations suffered from hostilities, damage by forest fires, pests, unregulated grazing and untimely care (Samofal 1925).

Archival materials of SE 'Shostkinske Forestry' and publications (Ogievsky 1905; Project of organization 2007; Samofal 1925) show that the experimental forest plantations were created for testing the influence

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of the width and direction of continuous felling on natural regeneration, agricultural techniques, and the methods of creating forest crops (sowing, planting), methods of mixing wood species, etc.

Research objects were studied only in the initial stages of their growth and development (Ogievsky 1905; Samofal 1925). Today, both natural stands and experimental forest plantations have reached maturity (Zhezhkun 2014; Redko et al. 2005).

Therefore, the purpose of our research was to evaluate the modern health condition, features of growth and productivity of research objects of Scots pine and to compare their efficiency at the age of maturity.

Material and methods

During 2008–2011, a retrospective analysis of cartographic materials was carried out in the territory of Sobytsky Forestry of SE 'Shostkynske Forest Enterprise' by the method of their superimposition on the plan of forest stands based on the forest inventory materials of 2007 (Project of organization 2007) and comparison of tree species composition and the age structure of planted and formed existing stands. The stands belonged to the same type of forest site conditions – dry poor pine stand with rather poor soil fertility.

In the process of identifying the location of experimental forest plantations, it was found that some stands were felled in previous years, but most of them formed age-old pine stands (Project of organization 2007). To determine the silvicultural and taxonomic parameters of stands, permanent sample plots (PSPs) were established in accordance with the generally accepted methods (Regulatory and reference materials 1987; Sample plots of forest inventory 2006). To determine the shape of the stands, a growth class was assessed for each tree according to G. Kraft. There were six categories of the health condition of trees: first – healthy, second – weakened, third – severely weakened, fourth – drying up, fifth – recently died and sixth – died over a year ago (Sanitary rules 1995). Dead trees also included windbroken and windthrown specimens. According to the number of all trees of each species, the middle class ac-

Table 1. Forestry and assessment parameters of Scots pine stands in the permanent sample plots

Parameters	PSP 6-Sb	PSP 7-Sb	PSP 8-Sb	PSP 9-Sb
	Stand composition			
	First layer 100% Scots pine + English oak, single silver birch	First layer 100% Scots pine Second layer 70% English oak, 20% Norway maple, 10% silver birch	First layer 100% Scots pine Second layer 80% silver birch, 20% English oak	First layer 100% Scots pine, single silver birch, English oak
Age, years	105	105	105	105
Average height, m	31.5	30.7	30.6	30.3
Average diameter, cm	38.0	35.3	33.4	33.5
Absolute density of stocking, $m^2 \cdot ha^{-1}$	50.5	First layer 41.8 Second layer 4.1	I 49.0 II 3.1	42.3
Relative density of stocking	1.06	First layer 0.82 Second layer 0.24	First layer 0.97 Second layer 0.21	0.87
Tree density: total/pine, trees ha^{-1}	577/419	1021/425	1090/555	530/475
Wood stock: total/pine, $m^3 \cdot ha^{-1}$	687/659	655/623	682/659	571/568
Mortality: total/pine, $m^3 \cdot ha^{-1}$	44/40	11/10	21/21	31/31
Dead wood: total/pine, $m^3 \cdot ha^{-1}$	10/10	8/8	12/9	49/49
Survival of stands, %	4.2	4.3	5.6	5.3
Site index class	1	1	1	1
Forest type	B_2dC	B_2dC	B_2dC	B_2dC

cording to Kraft and the average health condition index (HCI) were calculated. In the forest stands where forestry measures were not carried out for a long time with the removal of dead trees, forest debris was assessed additionally. The research data were processed according to the standard methods used in mathematical statistics using personal computers.

Results

In the spring of 1906, Scots pine plantations were created by planting 1-year-old seedlings in the clear-cuts of the meridional direction (North–South) with a width of 20 m (PSP 6-Sb) and 40 m (PSP 7-Sb). At the age of 105 years, the average height of the compared Scots pine stands did not differ significantly (Tab. 1). Stands were almost indistinguishable in density and survival and had a high relative density of stocking and the stock of stem wood.

However, tree mortality was 44 $m^3 \cdot ha^{-1}$ in the pine stand which formed on the narrower clear-cut (PSP 6-Sb) and was four times higher than in the pine stand on a wider clear-cut (PSP 7-Sb). Therefore, at PSP 6-Sb, the pine stand was very weakened (HCI = 2.57) and at PSP 7-Sb, it was weakened (HCI = 2.22, Tab. 2). Species diversity and crown closure of the second layer and undergrowth were greater in the age-old pine forest formed on a wider clear-cut than in the one formed on a narrower one.

The direction of a clear-cut site had a significant impact on the formation and productivity of stands. Total productivity of 105-year-old stands was 111 $m^3 \cdot ha^{-1}$ (16.2%) higher in the pine stand at PSP 8-Sb, which was formed on the felling site with the direction northeast–southwest than on PSP 9-Sbt that was located on the clear-cut directed from northwest to southeast (Tab. 1).

In the pine stand formed on the clear-cut with a direction from northeast to southwest, pine trees of the first category of health condition predominated, and in the stand with the direction from northwest to southeast, trees of the third category predominated (Tab. 2). The pine stand at PSP 8-Sb at the age of 105 was weakened (HCI = 1.79) but more viable compared to the very weakened stand at PSP 9-Sb (HCI = 2.92), which in previous years had accumulated a significant amount of dead wood (49 $m^3 \cdot ha^{-1}$), increasing the amount of combustible materials and worsening the fire safety of the stand.

Choosing the most effective way to create forest plantations is also important for the growth and formation of future stands. In the spring of 1907, at the 40-m-wide clear-cut, Prof. V.D. Ogievsky created Scots pine plantations in three ways (three sections):

Section 1 – alteration of one row of sowing of Scots pine seeds (20 seeds per running meter) and one row

Table 2. Distribution of Scots pine trees by categories of health condition

PSP	Proportion of Scots pine trees by categories of health condition [%]							HCI
	1	2	3	4	5	6	total	
1-Sb	44.0	40.9	5.8	–	–	9.3	100	1.99
2-Sb	41.2	36.3	4.7	–	–	17.9	100	2.35
3-Sb	29.3	43.1	17.3	–	4.4	5.9	100	2.25
6-Sb	37.3	30.0	10.9	1.8	–	20.0	100	2.57
7-Sb	23.6	43.6	28.6	1.4	3	1.5	100	2.22
8-Sb	34.8	31.4	23.7	4.2	1.7	4.2	100	1.79
9-Sb	1.0	33.0	53.4	4.9	1.0	6.7	100	2.92
10-Sb (sowing)	28.6	54.0	12.3	2.0	–	6.1	100	2.12
10-Sb (planting)	31.5	44.5	10.9	–	2.2	10.5	100	2.29
11-Sb	24.3	64.8	12.2	–	–	8.7	100	2.23
12-Sb	30.2	40.3	12.2	0.7	2.2	14.4	100	2.50

Note: HCI – health condition index.

Table 3. Forestry and assessment parameters of Scots pine stands created by sowing and planting

Parameters	PSP 10-Sb			PSP 11-Sb	PSP 12-Sb
	sown	planted	together		
Stand composition	100% Scots pine	100% Scots pine, single English oak	100% Scots pine, single English oak	100% Scots pine, single English oak	100% Scots pine, single English oak
Age, years	105	105	105	105	104
Average height, m	28.0	28.0	28.0	30.0	30.9
Average diameter, cm	33.9	34.0	34.0	37.0	39.2
Absolute density of stocking, $m^2 \cdot ha^{-1}$	16.5	28.8	45.3	45.3	43.3
Relative density of stocking	0.34	0.59	0.93	0.91	0.89
Tree density: total/pine, trees ha^{-1}	182/182	328/316	510/498	434/418	394/346
Wood stock: total/pine, $m^3 \cdot ha^{-1}$	207/207	362/362	569/569	604/603	580/568
Mortality: total/pine, $m^3 \cdot ha^{-1}$	14/14	27/25	41/39	51/45	41/35
Dead wood: total/pine, $m^3 \cdot ha^{-1}$	3/3	21/21	24/24	3/3	25/25
Survival of stands, %	1.3	2.3	3.6	3.1	2.6
Site index class	I	I	I	I	I
Forest type	B_2dC	B_2dC	B_2dC	B_2dC	B_2dC

of planting of 1-year-old seedlings according to the scheme of 1.5 × 0.5 m (PSP 10-Sb);

Section 2 – sowing of Scots pine seeds (20 seeds per running metre) with an interrow distance of 1.5 m (PSP 11-Sb) and

Section 3 – planting 1-year-old Scots pine seedlings according to the scheme of 1.5 × 0.5 m using seedlings taken from variant 2 in the spring of 1908 (PSP 12-Sb).

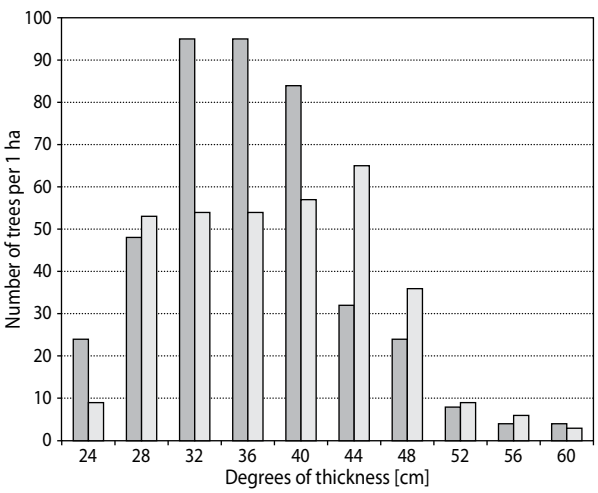

Figure 1. Distribution of Scots pine trees by the degree of thickness in PSP 11-Sb (dark) and PSP 12-Sb (light)

At 105 years of forest age, the average height and the average diameter of trees in variant 1 (PSP 10-Sb) created by sowing and planting did not differ significantly, but the Scots pine survival in planted sections was 1.3 times greater than in sown ones (Tab. 3).

The age-old pine stand was weakened, but no significant difference in the index of health condition was found for planted and sown sections. The volume of dead wood of Scots pine was 7 times greater in plantations created by planting than by sowing.

In Section 2, the survival of 105-year-old Scots pine plantations created by sowing was 19% greater than in Section 3 created by planting (PSP 12-Sb).

Regarding the health condition, the plantations created by planting and by sowing were weakened (see Tab. 2). The proportion of trees with the sixth category of health condition (died over a year ago) was greater in sown sections, and the proportion of trees with the fifth category of health condition and dead wood was greater in planted sections. The last fact testifies to the greater stability and adaptability of age-old artificial Scots pine stands created by seed sowing.

The distribution of trees by the degree of thickness in the aged stands was characterised by a right-hand asymmetry (Fig. 1).

The sharpness of the Scots pine tree distribution was much higher (E = 0.614) in the section created by sowing (PSP 11-Sb): most trees accumulated in the central degrees of thickness. At PSP 12-Sb, more trees were concentrated in the thin and thick degrees of thickness and the distribution had a negative excess (E = -0.509).

The wood stock of the pine element of the stand in the sections created by seed sowing was 35 $m^3 \cdot ha^{-1}$ (6%) larger than in planted sections.

The proportion of commercial timber (90.4%) was 9.1% higher and that of fuel wood was twice less at PSP 11-Sb than at PSP 12-Sb.

Productivity and stability of forest stands depend on the correct forest stand composition at planting. The composition of forest stands should correspond to the type of forest site conditions, and the mixing of species should take into account their interaction during their joint growth and development.

In the spring of 1906, on the initiative of V.D. Ogievsky, pure and mixed Scots pine plantations were created at a clear-cut of 53.6 m wide (direction: northwest–southeast).

The plantations were created by planting 1-year-old seedlings of Scots pine with the planting placement being 2.0 × 0.5 m. In mixed plantations, linden seedlings (*Tilia cordata* Mill.) were planted on two sides along the row near Scots pine seedlings.

The stands of experimental plantations at the age of 103 years were characterised by high productivity (Tab. 4). In terms of total productivity, the mixed planted pine and lime stand (PSP 2-Sb) exceeded planted pure pine stand (PSP 3-Sbt) by 1.2 times (by 124 $m^3 \cdot ha^{-1}$) and the natural one (PSP 1-Sb) by 1.6 times (by 302 $m^3 \cdot ha^{-1}$). However, the stock of pine wood in the age-old artificial pure stand was the largest, compared with the natural pine stand and the artificial mixed stand. More dead trees (dryness of previous years 78 $m^3 \cdot ha^{-1}$) had accumulated in the artificial mixed stand than in pure artificial and natural stands.

Accordingly, the average category of health condition of pine trees at PSP 2-Sb was lower (2.35) than in the compared stands (see Tab. 2). However, in mixed stands, the share of pine trees without signs of weakening was 1.4 times higher than in artificial pure pine

Table 4. Forestry and assessment parameters of Scots pine stands of different species composition and origin

Parameters	PSP 1-Sb	PSP 2-Sb	PSP 3-Sb
Origin	Natural	Planted	Planted
Forest species composition	First layer 100% Scots pine, single English oak	First layer 100% Scots pine + single silver birch Second layer 100% small leaved lime	First layer 100% Scots pine, single English oak, small leaved lime, wild pear, wild apple
Age, years	112	103	103
Average height, m	27.8	32.0	31.5
Average diameter, cm	35.0	41.5	38.2
Absolute density of stocking, $m^2 \cdot ha^{-1}$	37.2	First layer 46.1, Second layer 16.5	48.2
Relative density of stocking	0.72	First layer 0.92, Second layer 0.48	1.01
Tree density: total/pine, trees ha^{-1}	390/386	1324/335	611/410
Wood stock: total/pine, $m^3 \cdot ha^{-1}$	482/481	784/503	660/553
Mortality: total/pine, $m^3 \cdot ha^{-1}$	15/15	78/78	44/44
Dead wood: total/pine, $m^3 \cdot ha^{-1}$	–	28/28	16/16
Survival of stands, %	–	3.4	4.1
Site index class	1	1a	1a
Forest type	B_2dC	B_2dC	B_2dC

stands and almost approached the Scots pine stands of natural origin.

Discussion

In the mature stands of Ukraine today as well as at the beginning of the 20th century, clear felling of the main use has been mainly used. The width of clear-cuts has a significant impact on the subsequent forest restoration and formation. In the spring of 1906, Scots pine plantations were created by planting 1-year-old seedlings at the clear-cuts of clear main felling of the meridional direction (North–South) with a width of 20 m (PSP 6-Sb) and 40 m (PSP 7-Sb). It was considered that microclimatic conditions are better at narrow clear-cuts than at wide ones.

However, subsequent natural regeneration or the pine plantations at narrow clear-cuts were more suppressed by the walls of the mother pine stand than at the wide ones. At the age of 20 years, the average height of Scots pine plantations at the section with 20 m width in its central part was 5.3 m, which was 13% lower than at a 40-m-wide section. It is explained by the worse conditions of moistening in narrow forest stands during the entire growing season (Samofal 1925).

Species diversity and canopy closure of the second layer and undergrowth were also greater in the wider section than in the narrower one. Formation of not pure but mixed deciduous-pine stands is the goal of management in the pine forests of many countries, including Germany, where the area of pine forests occupies 22.3% of the area covered by forest vegetation (Lavny and Spatgelf 2016).

This is described in detail in the land programmes for the formation of target pine stands. Mixed deciduous-pine plantations have a number of forestry, economic and environmental advantages. In particular, they improve soil fertility compared to pure pine stands (Prietzel 2004), increase the resistance to diseases, increase the increment and productivity of stands (Pretzsch et al. 2013), enrich faunal biodiversity (Oldenburg and Müller 2004) and have many economic benefits (Schröder et al. 2006, 2010). In addition, under the tent of mixed pine stands, hydrological regime improves (compared with pure pine plantations) (Müller 2009), which allows them to better adapt to modern climate change.

The current 'Rules of felling of the main use' of Ukraine (The rules for main felling 2010) take into account the results of many studies conducted by domestic authors (Gordienko et al. 2002; Maurer et al. 2009; Redko et al. 2005); therefore, the width of the clear-cuts of mature Scots pine stands is now accepted at 50 m.

Pine plantations created in 1907 at clear-cuts of 20 m width with the direction of felling from northeast to southwest (PSP 8-Sb) already had an average height 21% higher by the age of 18 years than those in the section at the felling site with the direction from northwest to southeast (PSP 9-Sb) (Samofal 1925). The decrease in survival and deterioration of pine growth in the first years of life is explained by many researchers to be due to greater light and damage to trees in the morning by late spring frosts in such sites (Gordienko et al. 2002; Maurer et al. 2009; Redko et al. 2005). Instead, the location of stands from northeast to southwest for more than 100 years has contributed to the formation of a healthier and better quality stand. The stand is renewed by deciduous species, which is a very positive phenomenon to increase soil fertility, stand productivity and biodiversity. Plantations at this section are located across the prevailing winds, which have improved the conditions for hardwood seeds to reach the area from the forest walls.

Given the current trends of the world community in relation to forestry, the methods of natural reproduction of forests, or close to them, are gaining more and more recognition. One of these is the sowing of Scots pine seeds as the most popular tree species at the world market, which predominates in the forest lands of northeastern Polissya of Ukraine. Satisfactory results of growing Scots pine from seeds were obtained for 9 years at the forest lands of Kyiv Polissya and recommended for implementation (Fuchilo et al. 2012). A study of ways to create more than centuries-old pine stands in Sobytske Forestry has shown that both sowing seeds and planting seedlings are acceptable. However, a significant advantage of plantations created by sowing pine seeds is the high marketability of the stand. The economic benefits of this ecological way of pine growing are also obvious.

Studies in Sobytskyi Forestry have shown that more than century-old natural stands and mixed pine plantations have a high health condition. The proportion of pine trees without signs of weakening is 1.4 times

higher than in pure artificial pine plantations. In addition, German researchers have found that the hydrological regime is better under the forest canopy of mixed pine stands compared to pure pine stands (Fuchilo et al. 2012). Mixed stands are also better adapted to modern climate change. Such statements are in full agreement with our results: today the type of forest site conditions in Sobytske Forestry corresponds to fresh relatively poor conditions, while in the early 20th century, it was referred to as dry poor conditions (Samofal 1925).

Given the high rates of centuries-old natural stands of Scots pine, it is necessary to point out the possibility of their restoration on a larger scale in the forest lands of northeastern Polissya, Ukraine, not only in wet ecotopes but also in dry and fresh poor and relatively poor forest site conditions under the example of German foresters (Lavny and Spatgelf 2016). Based on the research of felling and reforestation in Sobitske Forestry for the period from 1906 to 1924, A. S. Samophal published his scientific work (Samofal 1925) which summarised the research carried out earlier and in other conditions by V.D. Ogievsky (Ogievsky 1905, 1966). He points out the great importance of agronomic care for natural regeneration in the process of its formation.

Even with minor manual care (removal of grass between plants during the growing season, removal of unhealthy seedlings) for the sixth year after felling, one can achieve the required number of natural regeneration. The success of both artificial and natural restoration, as a strategic direction in the development of forest science and practice, S. A. Samophal closely associated with soil moisture during spring and summer. A similar opinion is held by a number of later researchers (Gordienko et al. 2002; Kyrychok 2009; Maurer et al. 2009; Redko et al. 2005).

Conclusions

1. In the sections of experimental forest plantations created by the initiative of Prof. V.D. Ogievsky, highly productive age-old pine stands have formed. Both natural and artificial reforestation are acceptable in the conditions of fresh and dry poor site conditions of Eastern Polissya of Ukraine: the plantations have a high productivity and are biologically resistant to negative factors.
2. Pine stands of age 105 years created on clear-cut sites of 20 and 40 m width in the same forest site conditions almost do not differ in terms of survival, density and stock of stem wood. Parameters of health condition and species phytodiversity of forest stands are better at wider felling sites.
3. The direction of the clear-cut site from northeast to southwest contributed to the formation of more productive and viable pine stands, compared to the direction from northwest to southeast due to the positive influence of prevailing southwest winds during the growing season.
4. An aged pine stand created by seed sowing has higher productivity, better health condition and marketability, compared to a stand created by planting seedlings.
5. Age-old linden-pine plantations exceed 1.2 times the productivity of pure Scots pine plantations and are 1.6 times higher than the natural Scots pine stands.
6. At maturity, mixed Scots pine plantations have a larger proportion of viable pine trees without signs of weakening than pure Scots pine plantations, but they are inferior in this respect compared to natural pine stands.
7. In the northeastern part of Ukraine, the fresh relatively poor forest site conditions are suitable for growing pine stands of natural origin as well as man-made forest plantations of Scots pine of mixed composition by sowing seeds or planting seedlings.

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