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# NATURAL REGENERATION UNDER PINE STANDS IN FRESH PINE FORESTS OF ZHYTOMYR POLISSYA AREA (UKRAINE)

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## Abstract

Under unfavourable ecological and climatic factors pine plantations preserve the seeding abilities on forest plots. Provision of soil moisture (that directly depends on regular precipitations) during vegetative period is decisive for the appearance and preservation of young generation. Successful natural regeneration of more than ¾th of area is possible due to the pine undergrowth of even less than 10-year-old trees, accounting their vitality.

**Key words:** density of undergrowth, frequency, natural losses, pine undergrowth, vitality.

## Introduction

The largest forest areas in Zhytomyr district during last several years alongside with the biggest (among other districts of Ukraine) total cuttings (total cuttings of main utilization forests and total sanitary cuttings) are being regenerated. About 2/3 of forest plots are regenerated artificially, the rest are left for natural regeneration (Statistic … 2014).

The plots with excess moisture growing conditions are most often left for natural regeneration. Under moist and wet conditions often occurs together with the change of valuable tree species for con-comitant species, which is a negative phenomenon in forestry. Under these conditions the regenerative potential of valuable species in favourable for natural regeneration types of forest growing conditions is of little utilization (Mehalinskyy 1968, Maurer and Kolodiy 2005, Maurer et al. 2008), for example, Scots pine under the conditions of fresh and moist pine forest that prevail in the region (Turko et al. 2015, Fuchylo et al. 2011). According to the current normative documents (Felling rules 2009) less than 8 thousand trees per ha with height up to 0.5 m of vital pine undergrowth is considered to be sufficient under the condition of its even distribution. Although, according to the successful natural regeneration scale Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky (URIFFM) the estimation of the quantity of vital undergrowth depends foremost on its age. For 4- – 8-year-old trees 6 thousand trees per ha is considered sufficient and for 2- – 3-year-old trees – 12 thousand per ha (Pasternak et al. 1990).

In recent years the pine tree stands in Ukraine as well as in Europe (in Poland and Belarus in particular) have been found in extremely unsatisfactory state. Most scientists and practitioners consider it to be the result of deterioration of ecological and climatic conditions of the mentioned areas (Anonimous 2016, Anonimous 2017a, Anonimous 2017b, Chudak 2014). The lowering of groundwater level is one of the decisive factors affecting the drying out of pine plantations.

On the account of deterioration of sanitary conditions, because of the changes in Sanitary Rules (Sanitary rules … 2016) that allow thinning out the density up to rare growing trees by selective sanitary cutting, the question of regeneration of disturbed plantations is especially sharp. With the view of the above, extremely important is the formation of new forest generation from the undergrowth. So as occurrence and preservation of natural regeneration is a variable phenomenon that depends on ecological and climatic factors and on the farming activity of humans (Turko 1995), the goal of this research is to study the state of undergrowth of plantations free from any forestry activity during several years. Alongside with it, the research is aimed at the extent to which pine plantations weakened because of deterioration of ecological and climatic conditions are able to regenerate.

The goal of the research was to discover the following:

1. To research the level of mature and premature pine tree stands provision with reliable advanced growth of aimed species, Scots pine, in particular;

2. To determine the height, age structure and vitality of pine undergrowth;

3. To study the dynamics of occurrence and natural losses of Scots pine shoots.

## Material and Methods

To perform the above tasks we carried out the accounting of natural regeneration on 20 experimental plots. All objects were in Levkiv Forestry SE ‘Zhytomyr Forestry’, so as the largest areas of pine plantations growing under pine forest conditions were concentrated in this forestry.

In general, the criteria of selecting experimental plots were composition, age, origin, type of forest and vegetative conditions, density and absence of forestry measures for the last 3 years. Because of substantial volumes of carried out forestry measures in this enterprise (sanitary cuttings in particular) only 20 plots meeting the criteria have been chosen for the research. All plots were represented by premature and mature pure pine tree stands with stand density from 0.6 to 0.8. The type of forest is fresh fairly poor with oak and pine of artificial origin.

Among living above soil litter dominates green moss (*Dicranum polysetum* Sw., *Pleurozium schreberi* (Willd. ex Brid.) Mitt.), red bilberries (*Rhodococcum vitis-idaea* (L.) Avror.), heather (*Calluna vulgaris* (L.) Hull), and cereal vegetation (*Agrostis vinealis* Schreb., *Festuca ovina* L., *Festuca rubra* L. s. str., *Calamagrostis epigeios* (L.) Roth, *Poa pratensis* L.). The underbrush is sporadically represented by rowan tree (*Sorbus aucuparia* L.), hawthorn (*Crataegus monogyna* Jacq.) and sweetbrier (*Rosa canina* L.). The compositiont of living top soil litter and underbrush in every experimental plot was similar. In each experimental plot the accounting of natural regeneration was held along the merchantable lines that were made along the centre of spots. 100 $m^2$ of area at each spot were under calculations (Anonimous 2006). The calculations were exercised

on accounting sites of 0.5×0.5 m (Siruk et al. 2016) in size that were located along the merchantable line, the total length of which within every spot amounted 400 m. The accounting was held during August-September in 2016 and 2017 on the attached transects. The natural composition, vitality and size category were taken into account in calculations.

The estimation of vitality condition of Scots pine was made by applying the relative index – relative accretion (Saltykov and Tkach 2007). The investigation of its spectrum has been set into the basis of this method. This condition was reflected in the quantitative correlation of undergrowth of different rate of reliability (Zlobin 1976).

The analysis of vitality state spectrum of undergrowth predicts its grouping on the example of annual increment (accretion) of central axis. The correlation of crown increment for the last year and average increment of height (relative accretion of height) was used as index, allowing to estimate increment. The application of index permits (with certain subjective attitude) to single out the specimen with extinguished increment (to 0.5), progressive (0.5–1.5) and perspective. In the last group crown increment is 1.5 and more times higher than average increment of height for the whole growing period.

## Results and Discussion

The accounting of advanced growth on the experimental plots was carried out during 2016–2017. These years were essentially different, as to the weather conditions that greatly affected the occurrence and natural losses of understory. A very dry, without precipitations, vegetative period was observed in 2016 from July to October. It should be mentioned that a year preceding the research was similar in weather conditions. While 2017, on the contrary, was marked with great precipitations and moderate temperature during vegetative period. The accounting results of all experimental plots confirmed the shortage of advanced growth by 28 % averagely (min – 7 %, max – 59 %). The biggest losses were noticed in pine forests with shallow undergrowth up to 0.5 m of height prevailing. The losses of 1- – 3-year-old trees on some experimental plots amounted 60 %. As to the older trees of 4- – 8-year-old the losses were not significant (about 5 %). The density of natural regeneration as well as its distribution worsened. If in 2016 the average frequency of pine undergrowth amounted – 34 %, in 2017 this index decreased to 25 %. As to the composition, on almost 19 plots it was represented by pine underwood with separate specimen of oak and birch. Only one plot revealed natural regeneration of ordinary oak alongside with pine under the canopy of parent stand (Table 1).

If we take into account only the number of pine undergrowth not accounting the height, structure and viability, ¾th of experimental plots were provided with more than 8 thousand trees per ha in 2017. But so far as the main value represents fine (shallow) undergrowth of 0.5 m height, the amount of this category regeneration will exceed the stated limit on 10 out of 20 plots. According to the methods URIFFM (Pasternak et al. 1990) as to the age of undergrowth, regeneration on 17 out of 20 plots may be considered successful.

**Table 1. Characteristic of viable natural regeneration on experimental plots.**

| No sample plot | 2016 | | 2017 | | Composition of regrowth* |
|---|---|---|---|---|---|
| | Density, thousand pcs. ha$^{-1}$ | Frequency, % | Density, thousand pcs. ha$^{-1}$ | Frequency, % | |
| 1 | 32.8 | 44 | 27.2 | 37 | 10Ps |
| 2 | 56.8 | 74 | 39.4 | 54 | 10Ps |
| 3 | 43.2 | 48 | 31.8 | 43 | 10Ps |
| 4 | 20.0 | 30 | 8.3 | 16 | 10Ps |
| 5 | 37.6 | 50 | 29.5 | 44 | 10Ps |
| 6 | 21.0 | 30 | 13.2 | 22 | 10Ps |
| 7 | 30.8 | 50 | 24.8 | 37 | 10Ps |
| 8 | 29.0 | 44 | 12.3 | 21 | 10Ps |
| 9 | 14.2 | 28 | 11.2 | 18 | 10Ps |
| 10 | 17.6 | 30 | 8.9 | 16 | 10Ps |
| 11 | 29.8 | 44 | 25.6 | 38 | 10Ps |
| 12 | 13.6 | 28 | 7.3 | 14 | 10Ps |
| 13 | 8.2 | 13 | 6.3 | 12 | 10Ps |
| 14 | 25.2 | 39 | 17.3 | 30 | 10Ps |
| 15 | 28.8 | 37 | 25.3 | 35 | 10Ps |
| 16 | 14.1 | 24 | 10.1 | 17 | 10Ps |
| 17 | 2.1 | 5 | 1.8 | 4 | 10Ps |
| 18 | 9.3 | 21 | 7.4 | 13 | 10Ps |
| 19 | 1.4 | 3 | 1.3 | 3 | 6Ps 4Qr |
| 20 | 15.8 | 29 | 13.2 | 22 | 10 Ps |

*Legend: Ps – *Pinus sylvestris* L.; Qr – *Quercus robur* L.

Within the period of 2 years, the height structure of undergrowth experienced some changes. These changes on all experimental plots depended as on the ability of undergrowth to regenerate so on the ability to transfer from one size category to another. So as in 2016 the average part of shallow (fine) underwood amounted about 86 %, middle and large 13 % and 1 % respectively, in 2017 these accounting plots showed 58 % of shallow, 38 % of middle and 14 % of large underwood (Table 2).

As to the annual young seeding, that were not included into general accounting, it should be stated that they wer not noticed at all during the survey in September 2016, because of two months draught. Consequently, the part of shallow (fine) undergrowth was not affected by young seeding of previous year. In 2017 the moisture supply of top soil (due to regular precipitations) during vegetative period made it possible to observe young seeding of pine from 100 to 12,200 trees per ha on experimental plots (Fig. 1). However, the character of young seeding location is mostly uneven (average frequency 4 %).

**Table. 2. Height structure of underwood, %.**

| No sample plot | 2016 | | | 2017 | | |
|---|---|---|---|---|---|---|
| | < 0.5 m | 0.51–1.50 m | >1.50 m | < 0.5 m | 0.51–1.50 m | >1.50 m |
| 1 | 98.8 | 1.2 | | 95.2 | 4.8 | |
| 2 | 93.3 | 6.7 | | 82.4 | 17.6 | |
| 3 | 96.3 | 3.7 | | 91.5 | 8.5 | |
| 4 | 95.5 | 4.5 | | 86.8 | 13.2 | |
| 5 | 96.8 | 3.2 | | 67.5 | 32.5 | |
| 6 | 79.1 | 17.6 | 3.3 | 21.2 | 67.4 | 11.4 |
| 7 | 92.9 | 7.1 | | 75.8 | 22.2 | 2.0 |
| 8 | 96.2 | 3.8 | | 88.7 | 11.3 | |
| 9 | 74.3 | 23.2 | 2.5 | 27.7 | 65.2 | 7.1 |
| 10 | 89.8 | 10.2 | | 65.2 | 34.8 | |
| 11 | 95.6 | 4.4 | | 81.7 | 18.3 | |
| 12 | 64.7 | 33.8 | 1.5 | 2.8 | 80.8 | 16.4 |
| 13 | 92.7 | 7.3 | | 49.2 | 50.8 | |
| 14 | 91.7 | 8.3 | | 57.2 | 42.8 | |
| 15 | 99.0 | 1.0 | | 93.3 | 6.7 | |
| 16 | 100.0 | 0.0 | | 95 | 5.0 | |
| 17 | 61.9 | 38.1 | | 0.0 | 94.4 | 5.6 |
| 18 | 34.4 | 37.6 | 28.0 | 0.0 | 55.4 | 44.6 |
| 19 | 78.8 | 21.2 | | 23.1 | 76.9 | |
| 20 | 81.6 | 18.4 | | 57.8 | 42.2 | |

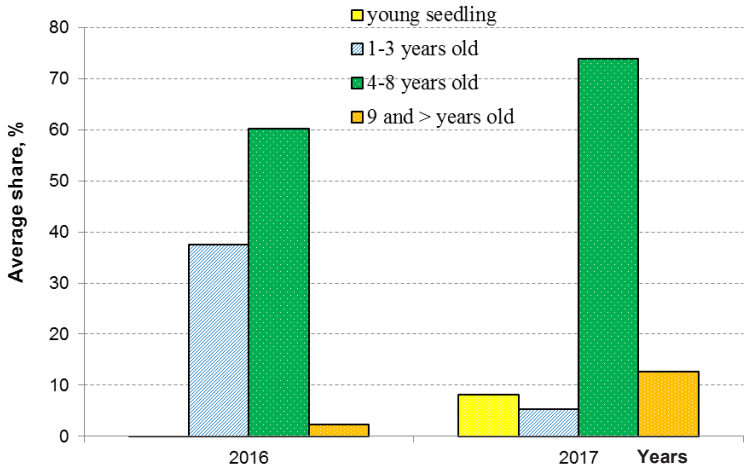


**Fig. 1. Advanced growth for age groups.**

The viability of shallow 1- – 3-year-old pine undergrowth was estimated visually. It should be noted, that the majority of shallow natural regeneration was viable with explicit increment and normal conifer sprouts at the moment of accounting. As to the medium and large undergrowth – the situation was more variable – part of it had a tendency to current increment reduction, though the conifer state of sprouts showed the signs of sound trees.

With the aim of determining viability of medium (0.5–1.5 m) and large (>1.5 m) pine undergrowth, the measuring of current medium increment of 30 pine specimen of each size category have been carried out. The specimen on the experimental plot were chosen accidentally, their number was connected with the level of probability (95 %) and with the variety of average undergrowth and height within size categories (on the level of 14 %) (Horoshko et al. 2004). For every pine tree the height, average and current increment (as to the height) has been determined (Table 3).

**Table 3. Average values of biometric measures of pine advanced growth.**

| No sample plot | Height gradation of undergrowth, m | Medium height of undergrowth X±m | Increment in height, cm | | Relative |
|---|---|---|---|---|---|
| | | | Medium, X±m | Current, X±m | |
| 6 | 0.5–1.5 | 0.68±0.02 | 0.12±0.01 | 0.13±0.01 | 1.08 |
| | >1.5 | 1.63±0.07 | 0.18±0.01 | 0.12±0.01 | 0.67 |
| 7 | 0.5–1.5 | 0.59±0.02 | 0.11±0.01 | 0.10±0.01 | 0.91 |
| | >1.5 | 1.57±0.06 | 0.19±0.01 | 0.14±0.01 | 0.74 |
| 9 | 0.5–1.5 | 0.63±0.02 | 0.14±0.01 | 0.09±0.01 | 0.64 |
| | >1.5 | 1.61±0.07 | 0.15±0.01 | 0.13±0.01 | 0.87 |
| 12 | 0.5–1.5 | 0.87±0.04 | 0.21±0.01 | 0.24±0.01 | 1.14 |
| | >1.5 | 1.65±0.08 | 0.20±0.01 | 0.17±0.01 | 0.85 |
| 17 | 0.5–1.5 | 0.73±0.03 | 0.18±0.01 | 0.18±0.01 | 1.00 |
| | >1.5 | 1.60±0.12 | 0.23±0.01 | 0.19±0.01 | 0.83 |
| 18 | 0.5–1.5 | 0.92±0.04 | 0.21±0.01 | 0.26±0.01 | 1.24 |
| | >1.5 | 1.77±0.09 | 0.24±0.01 | 0.22±0.01 | 0.92 |

Because of the existence of Scots pine undergrowth of different regeneration waves we have conducted calculations as to relative increment for medium undergrowth (4- – 8-year-old) and large (from 9-year-old) on the experimental plot.

Judging from the calculated medium values of relative increment for undergrowth of different size categories on experimental plots, it should be stated, that this index exceeded for medium undergrowth on all plots. The relative increment index for regrowth of 0.5–1.5 m of height fluctuated between 0.64 and 1.24. This index showed the perspectives of natural regeneration of this size on 4 from 6 experimental plots. The average values of relative increment for large undergrowth comparing to the medium turned to be somewhat smaller (from 0.67 to 0.92). The relative increment of medium undergrowth on 6 experimental plots was 19 % higher in general than the corresponding index of large undergrowth. This fact testifies to the decrease of pine viability with time under the canopy of parent stand.

According to the applied methods of viability estimation as to pine underwood,

populations are divided into prosperous, balanced and depressed (Zlobin 1976). In the first case the next condition should be present: half amount of frequently perspective (perspective increment) and medium depressed (progressive increment) are more frequent than heavily depressed (extinguished increment). In the second case – half amount of frequency of specimen without depression (perspective increment) and medium depressed (progressive increment) are equal to the frequency of heavily depressed specimen. The domination of heavily depressed specimen is typical for depressed cenopopulation.

The given below table (Table 4) confirms that the majority of medium and large undergrowth is perspective on the experimental plots. The progressive advanced growth of pine obviously prevails in the spectrums of experimental plots No 12, 17 and 18. Consequently. according to the applied methods, these populations' undergrowth can be called 'prosperous'. The research results for large undergrowth constitute close correlation of specimen with extinguished, progressive and perspective indices of relative increment, allowing to estimate the population state on experimental plot as 'balanced'. As to the average undergrowth of this sample, it is mostly perspective.

**Table 4. Fraction of advanced growth of various viability within size category, %.**

| No sample plot | Height gradation, m | Class of relative increment | | |
|---|---|---|---|---|
| | | Extinguished (0–0.49) | Progressive (0.5–1.49) | Perspective (≥1.5) |
| 6 | 0.5–1.5 | 16.7 | 70.0 | 13.3 |
| | >1.5 | 30.0 | 63.3 | 6.7 |
| 7 | 0.5–1.5 | 13.3 | 70.0 | 16.7 |
| | >1.5 | 36.7 | 40.0 | 23.3 |
| 9 | 0.5–1.5 | 40.0 | 50.0 | 10.0 |
| | >1.5 | 23.3 | 53.3 | 23.3 |
| 12 | 0.5–1.5 | 10.0 | 70.0 | 20.0 |
| | >1.5 | 23.3 | 50.0 | 26.7 |
| 17 | 0.5–1.5 | 6.7 | 90.0 | 3.3 |
| | >1.5 | - | 96.7 | 3.3 |
| 18 | 0.5–1.5 | 6.7 | 53.3 | 40.0 |
| | >1.5 | - | 93.3 | 6.7 |

Estimating the advanced growth of Scots pine on experimental plot 7 (only for large undergrowth) and on experimental plot 9 (only for medium undergrowth) as to the viability state, the populations of young generation under the canopy of mature stand could be called 'depressive', so as the part of 'extinguished' specimen of undergrowth exceeded half of the sum of progressive and perspective specimen.

## Conclusions

In spite of the enfeebled state of pine plantations, they preserve not bad ability to natural regeneration which is proved by the availability of young seeding of the current year (up to 12 thousands per ha in number). The occurrence and preservation of young seeding is directly connected with weather conditions during vegetative

period. The absence of precipitations for 2 and more months (example of 2016) under high temperatures led to perishing of seeding and one-year undergrowth. The losses of pine undergrowth of 3-year-old trees may reach 60 % a year, and older – up to 10 %.

In estimating the successful natural regeneration of Scots pine under the stand canopy, the methods of URIFFM seem to be appropriate, as they take into account undergrowth losses depending on its age.

Considering the viability of medium and large undergrowth the index of vitality should be applied. It is based on using the index of relative increment by height. Reliable is considered undergrowth when this index isn't lower than 1.

Over ¾th of investigated plots could be considered acceptable for natural reforestation being provided with necessary for natural regeneration measures.

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