Highly productive pine plantation growth on peat soils

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Abstract. The results of some sixty year researches concerning the pine plantation formation and development on a dried eutrophic-mesotrophic peatland developed by planting are discussed in paper. It is shown that rich peatlands covering millions of forest hectares and subjected to hydroamelioration are promising for accelerated cultivation of high-tonnage plantings. The growing stock is found out to presumably reach 525 m³/ha within 57 year-period of time. No regular thinning is necessary in the process of forest growing, it is only sufficient to remove naturally dried trees.

1. Introduction
The swamp area is about 110 million hectares in the forest fund of Russia. The largest part of the swamps is located in the North-Western regions of the European part of Russia and Siberia. Swamps are different in their potential wealth according to their water and mineral nutrition types. The transitional and lowland swamp soils are referred to the richest Russian Forest Funds. They occupy the territory of more than 50 million hectares in the North-West Region of the Russian Federation. Practical conclusions for fast-growing and highly productive pine crops are drawn and advices are offered after long-term studies performed in stationary test plots. It may be economically feasible to harvest wood at the quantitative ripeness stage in shorter time periods at such fast-growing plantations with target forest cultivation.

2. Methods of research
The studies have been conducted on permanent sample plots since establishing and forming the plantation. The structure of the peat deposits [1] and their water mode [2] have been studied. The planting taxation is carried out regularly. Soil conditions are studied, including the groundwater level observation in 0.8-1.0 m deep wells in accordance with the standard research technique [3]. The peat water permeability [4] is determined, as well as the groundwater decrease rate is calculated using the formula by Prof. Pisar’kov Kh A [5].

3. Result and Discussion
The silvicultural swamp drainage is a necessary condition. The potential fertility realization is impossible under excess moisture conditions. Therefore, a significant part of the “rich” swamps are covered with low-standing stands, or there is no forest at all. To improve soil formation conditions, it is necessary to regulate the water level values by means of draining wetlands. When the root area is drained, the excessive gravitational moisture is drawn away. Anaerobic processes are replaced by aerobic ones. The fundamental changes in soil-forming process are observed. However, the removal of gravitational (free) moisture from the root area should be understood as the drainage, but not their
wetland desiccation, especially with a small peat depth (capacity). Usually, it is limited to 30-50 cm depth. The peat deposit thickness can be several meters. Therefore, if the swamp is considered to be a water keeper, it will remain the same after draining.

Studies of the groundwater quality show that there is a constant lack of oxygen in swamp groundwater, even in the uppermost horizons. The O\textsubscript{2} content is not more than 7-8 percent of normal values. Some oxygen increase in upper groundwater horizons is observed only after heavy rains. But slightly increased oxygen content is maintained within 1-2 days. The oxygen content in the soil water is not increased even after draining. In such conditions, the dissolved oxygen traces are observed only in the upper groundwater horizons located somewhat deeper before draining. Studies show that the lack of oxygen is constantly observed in swamp soil waters. It is one of the main poor reforestation reasons, as well as the poor forest growth in the swamps.

Hygrophitic vegetation remains after draining for a long time and the moisture excess is preserved. The air mode is also of an adverse effect. If the total air content is sufficient, then the O\textsubscript{2} and CO\textsubscript{2} ratio is not always favorable for the forest growth. If there is a certain CO\textsubscript{2} amount and its concentration does not reach a certain critical level, normal microbiological processes take place in the soil, including aerobic respiration and CO\textsubscript{2} release. The microbiological processes are inhibited at high CO\textsubscript{2} concentrations. The CO\textsubscript{2} amount increase and the O\textsubscript{2} amount decrease are suspended. The system acquires its quasi-stable state. The soil – soil air system functions according to the homeostasis type at the certain O\textsubscript{2} and CO\textsubscript{2} ratio. The soil microorganism activities are reduced at high CO\textsubscript{2} concentrations stopping the O\textsubscript{2} absorption.

Poor soil aeration results in high CO\textsubscript{2} concentrations influencing the root system formation and the root propagation inwards. So, it is necessary to form wetland micro-elevations while cultivating forest plantations. They can be discrete - or continuous extended soil elevations. The layers are formed by arranging small grooves lengthways.

As a rule, it is necessary to arrange canals at certain distances in draining wetlands with existing tree stand, thus, providing the necessary drainage rate (groundwater depth).

When planting forest crops, especially after seeding, it is necessary to develop permanent conditions in order to provide the required drainage degree immediately after planting the forest crops.

Therefore, the territory preparation for planting forest crops in the swamps takes a special place. In addition to the ordinary open canal drainage, a network of shallow grooves - furrows is arranged with the help of the LKA-2 trencher. The furrows are laid at 3-4 meter distance. They are 0.35-0.40 m. deep forming two layers on both sides. The furrows are rolled by tractor tracks and solid layers (some 50-60 cm wide and 15 cm thick) are formed. The furrows are laid to the drainage channels network (Figure 1).
Studies reveal that the groundwater level depression curve is formed at 30-40 cm furrow depth with 3.5 m average intermediate distance as it is used in conventional channel drainage. The pressure magnitude can reach 15 cm, and then it declines quickly. The required water drainage time ($t$) can be calculated using the formula by Kh.A. Pisar’kov [1]:

$$t = \frac{\delta(h_1 - h_2)}{q_c + e}$$

(1)

where, $\delta$ - specific peat water loss; $h_1$ and $h_2$ - initial and final pressure, m; $q_c$ - middle runoff layer, m; $e$ - total evaporation.

The average runoff layer is calculated by the formula:

$$q_c = \frac{4K\delta L}{h_2}$$

(2)

where, $K$ - filtration coefficient, cm/s; $L$ - furrow spacing.

Observing pressure decrease values from 10 to 1 cm with the 0.016 cm/s filtration coefficient and a specific water loss value of 0.090, the drain layer makes up 3.5 cm/24 h. In the absence of precipitation, the groundwater level can be lowered by 10 cm in 36 hours, i.e. 5-6 cm/24 h.

The silvicultural furrows are laid into canals, thus ensuring constant drainage of water from them. It allows the roots to grow under the furrow bottom in the direction opposite to the row of plantings forming the equilaterally developed root system.

No oxygen is found out in the soil in case the furrows are not exempt from water. So, a one-sided root system grows especially on peatlands, on heavy clay soils, often causing planting windiness.

The CO$_2$ high concentration is a peculiar biological barrier preventing the roots to penetrate deeply into the soil. The CO$_2$ critical concentration in soil is more than 2-3 percent, actually its value may exceed 5-6 percent. The stands with a shallow root system are formed. In this case, the high-bonded stand may be formed though subjected to windfalls.

The preference should be given to pine species for planting crops on peat soils. The surface root system is formed in the initial planting period. The roots penetrate in 15-20 cm soil depth. As the plantings are growing with the lapse of time, the transpiration moisture consumption is increased. The groundwater level is lowered below the peat horizon and vertical roots [6] develop from horizontal roots and the second tier of horizontal roots develops from the taproot in the underlying mineral soil.
This two-tier root system improves plant nutrition and ensures planting stability with strong winds, preventing from their windiness.

The peat soils of eutrophic and mesotrophic marshes are sufficiently provided with the main nutrients - $N$, $P$, $K$; therefore, the stand is already characterized by its high growth in the first years.

Studies conducted in the Ushakinsky Forestry of Lisinsky Forest College show that the planting stock gains 50-60 m$^3$/ha by the ten-year period. High survival rate of crops and closure of crowns in rows (Figure 2). The reserve is 277 m$^3$/ha at the experimental plot in 32 years (Table 1). As for natural stands, such a volume of stock can be observed in 70-80 years [2], which is close to the tree felling time. At 43 years of age formed a closed pine plantation (Figure 3). After 45 years, the wood stock is 405 m$^3$/ha. When counted after 57 years, the wood stock is 525 m$^3$/ha.

![Image](image_url)

**Figure 2.** Pine culture 1964.
Figure 3. Culture pine at the age of 43 years.

Table 1. Forest survey characteristics of pine plantations over time periods.

| Age, years | Average Height, m | Average Diameter, cm | Stand Density | Forest Appraisal Index | Growing Stock, m³/ha | Mean Annual Increment, m³/ha |
|------------|-------------------|----------------------|---------------|------------------------|-----------------------|-----------------------------|
| 19         | 8.9               | 9.6                  | 1.0           | I                      | 131                   | -                           |
| 32         | 16.1              | 14.2                 | 1.1           | Ia                     | 277                   | 11.3                        |
| 45         | 22.3              | 18.9                 | 1.08          | Ia                     | 405                   | 9.8                         |
| 57         | 26.2              | 21.7                 | 1.08          | I                      | 525                   | 9.6                         |

The natural forest stands with a smaller stock are often subjected to felling after 90-100 year period of time. These peculiarities can be taken into account in target forest growing, which makes it possible to recoup the costs of drainage and silvicultural territory cultivation within a shorter period [7].

For example, there are about 3000 hectares of compactly located eutrophic and mesotrophic marshes in the Kirishsky logging enterprise (Leningrad Region). The target peatland drainage can be arranged there. The reclamation costs can be recouped within a relatively short period of time with regard to the forest growing peculiarities.
4. Conclusions
1. Solely eutrophic and mesotrophic marshes are suitable for developing highly productive plantations.
2. It is necessary to arrange a relatively rare network of drainage channels. The main groundwater regulation mode is provided with the help of silvicultural furrows.
3. Silvicultural furrows are performed by a two-tail plow of a trencher (Model LCA-2).
4. Furrows must be connected to the drainage network diverting the water into water intakes.
5. Silvicultural tending can be limited by gradual extraction of dead trees, by improving growth conditions and reducing the possibilities of forest fires, especially crown ones.

References
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