Dependence of growth of annual seedlings of *Pinus sylvestris* L. on the average temperature and sum of precipitation of growing season in Kazakhstan

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**Abstract.** The purpose of the research is to determine the rate of influence of weather conditions on the rapidity of growth of planting stock of *Pinus sylvestris*. The objects of research were annual seedlings of *P. sylvestris* growing in forest nurseries of Pavlodar, North Kazakhstan, Akmola and Municipal Public Institution “Forestry Institution “Bukpa” Regions. At the highest average temperature of the growing season and a lower sum of precipitation in the Pavlodar region, the best indicators of the quality of *P. sylvestris* seeds were observed over the three-year period of research. When the air temperature is high enough during the growing season, there was faster growth of the seedlings in the first year of cultivation in all regions. Low temperature regime affected the height of seedlings in several nurseries. Close positive relationship was established between the rainfall and the diameter of the root neck, as well as the root mass (R=0.82 and 0.73, respectively) for seedlings from the nursery in North Kazakhstan. Therefore, despite regular watering in the forest nurseries, some growth indicators are very dependent on the rainfall during the growing season, and an increase in air temperature has a positive effect on the rapidity of growth of seedlings.

1. Introduction

Pine, as the most plastic species, can be a phyto indicator of the state of the environment, including climate change, since it belongs to the most sensitive tree species. Climatic conditions such as temperature and rainfall are decisive factors for the spread of plants on a global scale [1], as they strongly affect germination, growth and survival of seeds at a population scale [2–4]. Temperature optima for many plants are in the range of 15–30°C, for annual seedlings of Scots pine, the sum of temperatures above 10°C should be about 3000°C.

Optimal soil and climatic conditions play an important role in the cultivation of tree planting material. The geographical limits of the distribution of plant species are usually more susceptible to climate change, since environmental conditions are often at the limit of tolerance for such species [5]. This ecological marginality can lead to lower relative fertility and lower density of the local population [6], which can lead to reduced resilience in unfavorable climatic conditions. Heat supply depends on the amount of light energy, and the rhythm of seedling development depends on the length of the daylight hours. Each geographical origin has a critical photoperiod due to the sensitivity of conifers to the length of the daytime [7]. With early sowing of pine and spruce seeds in containers at...
the onset of the critical day length, the apical bud is laid at the end of July and the seedlings reach standard sizes by the end of the first year of life [8-10]. For Scots pine, an increase in a long light period allows one to accelerate and increase in the growth of seedlings and their resistance to unfavorable environmental factors [11]. The thermal regime increases the photosynthesis of young plants; in order to obtain a large number of seedlings and stable seedlings, the average daily temperatures should be from 14 to 25°C, and for the intensive growth of the root system, an even higher temperature is needed, totaling to about 240°C [12]. The dependence of the growth of the phytomass of Scots pine seedlings on heat supply and relative air humidity was established [13]. Although warming can promote seedling establishment in trees [14-16], seedlings are susceptible to drying out during the growing season, and this effect can increase with increasing temperature. For this reason, an increase in precipitation can promote seedling rooting much more than the warming effect, or even stimulate a warming response [17-18], but the interaction and the effects between the temperature and precipitation remains unclear. If some unfavorable soil features can be corrected or improved through the use of agricultural technology, then light and heat cannot be controlled. In especially unfavorable conditions, the only solution in this situation is to grow planting material in a closed ground with a stable microclimate. Therefore, it has been suggested that changes in other environmental factors may alter the response of tree seedlings to warming, precipitation [19-20] and the composition of existing vegetation in which tree seedlings need to adapt [21-22]. However, the extent and mechanisms by which precipitation and local plant communities affect the temperature and growth rate of seedlings have rarely been experimentally studied [23] and therefore, remain poorly understood.

1.1. Purpose of Research
Determination of the degree of influence of weather conditions on the growth rate of planting material of Scots pine.

2. Methods and Materials
The objects of research were Scots pine seedlings of the first year of cultivation, growing in forest nurseries of Pavlodar (SFNR “Yertis ormany”), North Kazakhstan (Arykbalyk branch of SNNP “Kokshetau”), Akmola (Branch of the Northern Region of the Republican Forest Selection and Seed Center (BNR “RFSSC” and MPI “FI “Bukpa”) regions. The soils in the forest nurseries of the North Kazakhstan and Akmola regions are chernozem, in the nursery of the SFNR “Yertis ormany” - sandy loam. The climate in all study regions is sharply continental with low winter and high summer temperatures.

The sowing of seeds was carried out according to the technologies adopted in each forestry institution, agrotechnical care was carried out for seedlings and young plants.

Two indicators were chosen - the average air temperature for the growing season (from May to October) and the amount of precipitation for the same period (table 1). Weather data were taken from the information site [24].

| Year | MPI “FI “Bukpa” | Arykbalyk branch of SNNP “Kokshetau” | SFNR “Yertis ormany” | BNR “RFSSC” |
|------|------------------|--------------------------------------|----------------------|-------------|
|      | Temperature (°C) | Sum of precipitation (mm) | Temperature (°C) | Sum of precipitation (mm) | Temperature (°C) | Sum of precipitation (mm) |
| 2017 | 13.07            | 29.14 | 12.47 | 34.57 | 14.16 | 30.29 | 12.17 | 26.57 |
| 2018 | 12.03            | 50.71 | 11.91 | 45.14 | 13.20 | 42.14 | 10.74 | 70.43 |
| 2019 | 13.06            | 34.14 | 12.77 | 34.29 | 14.01 | 27.14 | 11.79 | 51.86 |
The height of the seedlings was measured in 100 growing plants on the registered sections [25]. The length of roots and stems was determined in 50 dug seedlings, starting from the root collar. Measurements were made with a ruler with an accuracy of 1 mm.

The collected material was processed by the methods of mathematical processing in accordance with the methods generally accepted in biological research [26]. The correlation method was carried out using the Statistica10 program.

3. Results and Discussion
It is well known that the setting of fruits and seeds is greatly influenced by weather conditions during this period. The absence of wind and precipitation during flowering reduces the range of dispersal of pollen, as a result of which under-pollination of Scots pinecones occurs. Also, weather conditions determine the size of the yield, and affect the quality of the seeds.

During the quality examination of Scots pine seeds that were collected in various regions of Kazakhstan and the observation of the dynamics of its change, it was decided to check the degree of influence of weather conditions in the year of seed ripening and in the previous year, when the cones are laid. In the BNR “RFSSC”, seeds that were used for sowing were collected from the tested, cloned and seeded crops of plus trees, which indicates their selected breeding value. In 2018, seeds of breeding origin had the highest quality indicators (table 2). In 2019, like almost all seeds from different regions displayed minor reduction in their performance in all positions.

| Seed quality indicators | SFNR “Yertis ornany” | BNR “RFSSC” | Arykbalyk branch of SNNP “Kokshetau” | MPI “FI “Bukpa” |
|-------------------------|----------------------|-------------|-------------------------------------|-----------------|
|                         | 2017     | 2018     | 2019     | 2017     | 2018     | 2019     | 2017     | 2018     | 2019     | 2018     | 2019     |
| weight 1000 pcs (g)    | 8.6      | 10.1     | 10.7     | 7.8      | 11.5     | 6.5      | 6.2      | 7.8      | 6.6      | 6.6      | 5.96     |
| purity (%)              | 98.6     | 98.0     | 98.8     | 99.7     | 99.0     | 95.5     | 99.5     | 99.2     | 98.5     | 98.0     | 97.1     |
| germination (%)         | 42.0     | 72.0     | 77.0     | 24.0     | 87.0     | 71.0     | 35.0     | 56.0     | 64.0     | 72.0     | 67.0     |
| germination energy (%)  | 24.0     | 70.0     | 73.0     | 11.0     | 86.0     | 50.0     | 33.0     | 56.0     | 61.0     | 34.0     | 65.0     |

Figure 1 shows data on the main indicators of seed quality and weather conditions in the year of setting cones and ripening of seeds. In the Pavlodar region, the best indicators of the quality of Scots pine seeds were observed for the entire period of the research, which could have been influenced by the higher temperature of the growing season. The low weight of seeds and their germination in 2017 is due to the difficult weather conditions of the previous year, the time of laying the cones - in October 2016, the average air temperature dropped to -1°C, in September precipitation was 1 mm, which is not typical for long-term observations.

In other regions, seed quality was low in all years of the study. A consistently low mass of 1000 seeds were observed in MPI “FI “Bukpa”, the germination energy fluctuated within 34-65%, and the impact of soil germination was quite high.

Let us consider the influence of weather conditions on the growth rates of annual seedlings of Scots pine. In 2017, the experiments were carried out only in 2 nurseries of Pavlodar and North Kazakhstan regions. The height of the seedlings in the SFNR “Yertis ornany” was 37.8% higher than that of the seedlings from the Arykbalyk branch of SNNP “Kokshetau”. This year, the average air temperature of the growing season in Pavlodar region exceeded by 2 degrees, and the total amount of precipitation for the same period was 4.28 mm lower than in the North Kazakhstan region.
Figure 1. The main indicators of the quality of Scots pine seeds and weather conditions during the setting of cones and ripening of seeds.

In 2018, seedlings from Arykbalyk branch of SNNP “Kokshetau” were distinguished by the smallest growth, while the largest growth was observed in the SFNR “Yertis ormany” (Table 3).

In the year of observations, the lowest air temperature was in the Akmola region, at the location of the BNR “RFSSC” - 10.74°C, with the highest amount of precipitation - 70.4 mm. Also, low air temperatures prevailed in the Arykbalyk branch of SNNP “Kokshetau”, where the seedlings had small growth. It should be noted that of all the years of setting up the experiments, the year of 2018 was the most unfavorable for the growth of Scots pine seedlings.

Table 3. Average indicators of annual seedlings of Scots pine by region.

| Observation year | Location of the nursery                                      | Average indicators (cm) |              |              |
|------------------|-------------------------------------------------------------|-------------------------|--------------|
|                  |                                                             | height                  | stem length  | root length  | stem diameter |
| 2017             | Arykbalyk branch of SNNP “Kokshetau”                        | 1.8±0.10                | -            | -            | -             |
|                  | SFNR “Yertis ormany”                                         | 2.9±0.20                | -            | -            | -             |
| 2018             | BNR “RFSSC”                                                 | 2.3±0.05                | 12.0±0.46    | 2.8±0.12     | -             |
|                  | Arykbalyk branch of SNNP “Kokshetau”                        | 1.5±0.05                | 6.6±0.50     | 3.0±0.20     | -             |
|                  | MPI “FI “Bukpa”                                             | 3.0±0.07                | 14.5±0.40    | 2.8±0.08     | -             |
|                  | SFNR “Yertis ormany”                                         | 3.9±0.09                | 10.8±0.50    | 3.4±0.30     | -             |
| 2019             | BNR “RFSSC”                                                 | 2.1±0.08                | -            | -            | -             |
|                  | Arykbalyk branch of SNNP “Kokshetau”                        | 0.8±0.08                | 2.41±0.21    | 13.90±0.09   | 0.07±0.20     |
|                  | MPI “FI “Bukpa”                                             | 1.20±0.11               | 2.68±0.20    | 10.63±0.12   | 0.12±0.21     |
|                  | SFNR “Yertis ormany”                                         | 4.1±0.13                | 5.57±0.14    | 17.60±0.99   | 0.10±0.20     |

The year of 2019 was characterized by the highest growing season temperature and little rainfall. The highest average height was distinguished by the seedlings from the SFNR “Yertis ormany” - 4.14 cm, in other regions, height was significantly lower. In the nursery of the BNR “RFSSC”, almost all sown seeds and seedlings were damaged by birds, so the observations were carried out on a smaller number of seedlings. The ratio of the length of the roots to the length of the stems was 3.2-5.7. The
seedlings from the Arykbalyk branch of SNNP “Kokshetau” stood out substantially, having the smallest stem length, where the length of their roots was more than 10 cm.

It is well known that the rate of growth is influenced by many factors, including soil conditions, but the optimal temperature regime is also an important condition. To identify the degree of influence of weather conditions, a correlation analysis was performed. As a result, close relationship was revealed between the length and weight of the stems (R = 0.90) in the seedlings from the SFNR “Yertis ormany” (table 4). The analysis also included the main weather indicators of the growing season. It was determined that there is a close positive correlation between the mass of the stem, the average temperature, and the amount of precipitation (R = 0.86 and 0.90, respectively).

Table 4. Correlation between growth rates and weather conditions in the nursery of SFNR “Yertis ormany”.

| Indicators                        | stem height (cm) | root length (cm) | diameter (mm) | stem weight (g) | root mass (g) | temperature of vegetation period (°C) | sum of precipitation (mm) |
|-----------------------------------|------------------|------------------|---------------|-----------------|---------------|--------------------------------------|---------------------------|
| stem length (cm)                  | 1.00             | 0.18             | 0.24          | 0.02            | 0.07          | 0.28                                 | 0.27                      |
| root length (cm)                  | 0.18             | 1.00             | 0.33          | 0.38            | 0.90          | 0.23                                 | 0.32                      |
| diameter (mm)                     | 0.24             | 0.33             | 1.00          | 0.44            | 0.50          | 0.12                                 | 0.60                      |
| stem weight (g)                   | 0.02             | 0.38             | 0.44          | 1.00            | 0.38          | 0.86                                 | 0.90                      |
| root mass (g)                     | 0.07             | 0.90             | 0.50          | 0.38            | 1.00          | 0.29                                 | 0.13                      |
| temperature of vegetation period (°C) | 0.28             | 0.23             | 0.12          | 0.86            | 0.29          | 1.00                                 | 0.75                      |
| sum of precipitation (mm)         | 0.27             | 0.32             | 0.60          | 0.90            | 0.13          | 0.75                                 | 1.00                      |

Analysis of variance (table 5) showed that the low probability of the null hypothesis (p = 0.000) allows it to be rejected, indicating significant effect on the growth of seedlings of the average temperature of the growing season.

Table 5. Analysis of variance results.

| Sum of Sq. | Deg. Of Freedom | Mean Sq. | Sum of Sq. error | Deg. Of Freedom | Mean Sq. | F | p |
|------------|-----------------|----------|------------------|-----------------|----------|---|---|
| 130.94     | 2               | 65.47    | 41.23            | 76              | 0.54     | 120.67 | 0.000 |

Correlation analysis was carried out for seedlings of all regions and the following results were obtained. There was a close correlation between the diameter and the weight of the stem and root (R = 0.92 and 0.97, respectively); and between the mass of the stem and the mass of the root (R = 0.97) in the Arykbalyk branch of SNNP “Kokshetau”. Moreover, all these correlations are significant at the p level. The relationship between growth indicators and weather conditions was observed only with the amount of precipitation and the diameter of the root collar, as well as the mass of the root, which had positive values (R = 0.82 and 0.73, respectively).

For the seedlings from MPI “FI “Bukpa”, significant relationship was observed between the length of the stem and the weight (R = 0.93), as well as between the length of the root and the amount of precipitation (R = 0.95). A less close relationship was characterized by the length of the root and the diameter of the root collar with the average temperature of the growing season (R = 0.70 and 0.77, respectively).
4. Conclusion
Some cyclicity of the seed quality indicators was revealed depending on weather conditions. With the highest average temperature of the growing season and a lower amount of precipitation in Pavlodar region, in comparison with other considered regions, the best indicators of the quality of Scots pine seeds were observed for the three-year study period. In other regions, the seed quality was poor. A sufficiently high air temperature during the growing season had a positive effect on the faster growth of seedlings of the first year of cultivation in all regions. In the nursery of the of BNR “RFSSC” and MPI “FI “Bukpa”, low temperature regime has influenced the height of the seedlings, but despite the fact that in the BNR “RFSSC” the seeds were of the improved category, their growth was more significant than in the other nursery. For the conditions of the SFNR “Yerts ormany”, the average temperature and the amount of precipitation were very closely related to the mass of the stem, and the correlation was positive. For the seedlings from the nursery SNNP “Kokshetau”, close positive relationship was established between the amount of precipitation and the diameter of the root collar, as well as the weight of the root. For the seedlings from MPI “FI “Bukpa”, significant relationship was established between the length of the stem and the mass, as well as between the length of the root and the amount of precipitation. The association between the length of the root and the diameter of the root collar with the average temperature of the growing season was not significantly immediate. Therefore, despite regular watering in forest nurseries, some growth indicators are very dependent on the amount of precipitation during the growing season, hence the increase in air temperature has a positive effect on the growth rate of the seedlings.

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