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The influence of atmospheric pollution on the growth and development of pine in the conditions of the Irtysh Semipalatinsk region

The wide range of common pine (*Pinus sylvestris* L.), its growth in different climatic zones and environmental conditions led to changes in morphological differences. The object of study is a ribbon woods population of pine (*Pinus sylvestris* L.) within the Irtysh region of the Semipalatinsk region. The article presents data on the growth dynamics of annual shoots of *Pinus sylvestris* in conditions of various gas contamination. The comparison of morphometric parameters of growth of pine shoots on three test areas, including the control area, was carried out. The pilot site was located within the city of Semey, the area of the Silicate plant (pilot site, Semey N 50.468442, E 80.212024) is considered the most polluted, two control areas were laid at a distance of 35 km (control area, Kashtak village, N 50.3983, E 80.6248) and 60 km from the city along the Borodulikha highway (control area, Borodulikha village, N 50.7336, E 80.8865). In an article describes the morphometric method of studying trees. For quantitative estimates of anthropogenic impact on the environment, data on the growth of woody plants are used, namely the study of the growth dynamics of annual shoots and pine needles. Based on this, 10 model pines were selected for the study at each site, aged 25–30 years, 6–9 meters high, d 24–36. The study of the length of the needles of experimental and control plants gave a clear characteristic of the changes arising under the influence of industrial pollution. As for the *Pinus sylvestris* growing in Priirtyshye, defined terms of the beginning, the termination, duration of visible gain.

Keywords: pine, shoots, trunk, skeletal roots, periodicity of growth, linear and radial growth, morphometric method.

Introduction

Emissions of harmful substances are concentrated mainly in industrial areas, where factories, transport, boilers are concentrated. Transport and thermal power plants account for a significant share of emissions in large cities. Emissions from industrial enterprises are one of the main causes of disruption of the sustainable functioning of ecosystems, including forests, causing their partial or complete degradation [1, 2].

In the new ecological situation plants play an important hygienic role, many plant species have the ability to extract from the atmosphere and accumulate various toxic gaseous compounds [1, 2].

The main object for assessing the state of forests in the Semipalatinsk region is the common pine (*Pinus silvestris* L). This is due to its wide range, as well as an important ecological role and economic importance. One of the most frequently used parameters for assessing the impact of industrial pollution, diagnostics of forest ecosystems is the morphometric method of the plant organism, since the morphological parameters of the plant are very sensitive to changes in growing conditions.

The degree of damage to species is directly dependent on the rate of absorption of gas and the intensity of gas exchange. Depending on the gas absorption, there are 2 types of damage, acute and chronic. Acute is noted with short-term exposure to plants of high concentrations of phytotoxicant, chronic — at low concentrations, but a long period of action [1, 2].

Pine is a qualitative bioindicator of the environment, so the choice of pine as a bioindicator is not accidental. To assess the state of atmospheric air for many years (2015–2019), we use the bioindicator pine (*Pinus sylvestris* L.). It is well known that it is a species that responds to pollution. This phytoindicator is widely distributed throughout the North-Eastern part of Kazakhstan, grows both on dry sands and in conditions of excessive humidity. In this regard, pine is a convenient object for bioindication of pollution levels in any area. Reactions of *Pinus sylvestris* L. to the presence of pollutants in the air reflect the overall level of environmental pollution with chemicals of various types. To assess the chemical load on the plant, its different characteristics are used. The morphological approach is the most common and easiest to implement [3]. In various literature sources as indicative signs it is recommended to use the value of the annual growth of the main shoot, the length of the leaf blade, the size of the generative organs [4]. Morphological and anatomical characteristics of

pine needles can also be used for indicative purposes. According to the authors, pine needles can be used as a bioaccumulator of aerogenic pollution [5, 6]. This is due to the fact that pine needles have the ability to effectively absorb pollutants, in particular, metal compounds, in the form of aerosols due to the diffusion deposition of the latter in the cavities and air channels of the leaf blade.

Recently, data on the growth of woody plants, namely, the study of the growth dynamics of annual shoots and pine needles, have been used more often for quantitative assessments of the anthropogenic environmental impact [7].

Materials and methodology

Our research was aimed at understanding the nature of the growth and development of pine (*Pinus sylvestris* L.) due to air pollution. In the spring of 2019, we began a study of the growth and development of Scots pine in the conditions of the Irtysh region of the Semipalatinsk region. The study was carried out at certain test sites (№ 1, 2, 3). Site № 1, the area of the Silicate Plant (experimental site, Semey N 50.468442, E 80.212024) is considered the most polluted. According to the data of the stationary observation network, the level of air pollution in the city is characterized as a high level of pollution, it is determined by the values of highest repeatability = 21 % (high level) and SI equal to 3 (high level) for phenol in the area of post № 4 (343 district, the area of the Silicate Plant 13/2) [8, 9].

Two areas (control site № 2, 3) were laid in a pine forest, they were located at a distance of 35 km (control plot, the area of the village of Kashtak, N 50.3983; E 80.6248) and 60 km from the sources of pollution along the Borodulikha highway (control plot, the area with Borodulikha, N 50.7336, E 80.8865). There are no large industrial facilities near the control plots, therefore, these research points were chosen. There is no data on air pollution in these areas.

For the study, we selected trees aged 25–30 years, height 6–9 meters, diameter 24–36 cm. The measurement was carried out with a measuring fork (pachymeter). The measuring fork serves to measure the diameters of the trunks of trees (Fig. 1) [10].
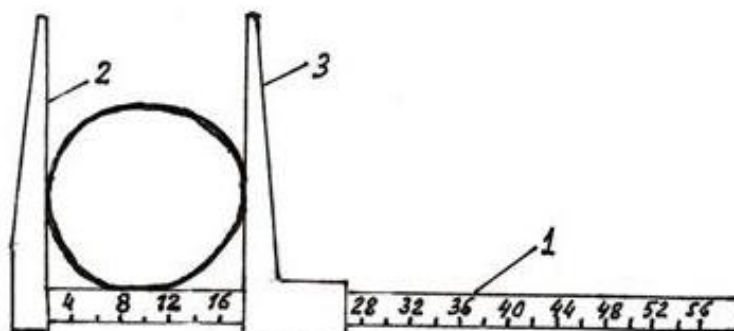

Figure 1. Measuring plug (pachymeter)

It can also be used to measure the height of trees (Fig. 2). At all sites (control and experimental), the studies were carried out on the same days.
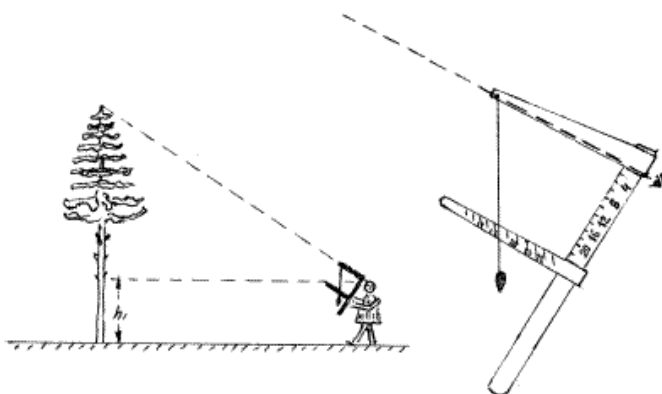

Figure 2. Measuring the height of a tree with a measuring fork

The influence of gas pollution on the growth and development of pine was studied by measuring the annual growth of shoots. For this purpose, took shoots in the middle part of the crown (repeatability 5 — fold, and in some cases 10 — fold).

Statistical data processing was performed using the Student's t-test calculation method [11].

Experiments and discussion

Morphological analysis

A comparative study of the annual growth showed that the value of the growth of shoots in experimental plants is less than in control plants (Table 1).

T a b l e 1

**Annual growth of shoots of common pine in the experimental and control sections
of the pine forest of the Irtysh region of the Semipalatinsk region**

№ site	Place of growth	Annual growth of shoots, cm				
		2015	2016	2017	2018	2019
№ 1 (experimental site)	The area of the Silicate Plant Semey N 50.468442, E 80.212024	9,7±0,8	9,36±0,65	7,6±0,1	7,6±0,3	7.3±0,21
№ 2 (control site)	The area of Borodulikha village N 50.7336, E 80.8865	11,5±0,12	10,8± 0,11	8,2±0,1	8,8±0,1	8±0,1
№ 3 (control site)	The area of the village of Kashtak N 50.3983, E 80.6248	11,5 ± 0,11	10,9±0,11	8,4±0,1	8,7±0,12	8,7±0,1

Among the control plants, the highest growth was found in model pine trees growing on the territory of the pine forest control area of the Borodulikha village, GPS coordinates: N 50.7336, E 80.8865 (plot number 2). Length of annual shoot growth of trees on this site in different years varies from 8 to 11.5 cm (p <0.05) while the second control section, the area of the village Kashtak (section № 3), the GPS coordinates: N 50.3983, E 80.6248 shoot growth of trees from 8.4 to 11.5 cm (p <0.05), and the smallest shoot growth shows experimental plot area Silicate plant, the GPS coordinates N 50.468442, E 80.212024 from 7.3 to 9.7 cm. According to the data, given in table 1, we can say that as the degree of anthropogenic load increases, the length of the shoot of pine decreases. Thus, from the data obtained, it can be determined that the ordinary pine has not completely lost its ability to respond to changes in external conditions, and also that the pine has morpho-metric limits of viability, which also depend on the external load.

Terms of growth of shoots and needles of Pinus sylvestris L.

The analysis of phenological data shows that under the influence of industrial pollution of the atmosphere, the annual growth of the pine tree is slowed down.

In the conditions of Semey of Irtysh, the growth of shoots of common pine begins on May, 10–12, and ends in mid-July. 10–15 days after the start of shoot growth, the beginning of the growth of needles is noted. The maximum duration of shoot growth is 64 days, needles 68 days.

A comparative study of the growth of shoots and needles by season showed that atmospheric pollution has a certain impact on the seasonal development of vegetative organs.

The growth of shoots in experimental plants began 5–6 days later compared to the control. In addition, we noted that the experimental plants are characterized by a reduction in the duration of growth of shoots and needles. So have pine, growing in city of (experienced) period growth 50 days, in the same time have in control sites 62–64 days.

When analyzing the phenological phase of pine, we noted that the experimental and control plants have different periods of development phases. In experimental plots the phenological stage occurs at 5–6 days later and ends by 8–9 days earlier.

The work of a number of researchers indicates the effect of gas contamination on the anatomical and morphological structure of leaves of woody plants [1, 2].

In this regard, we conducted a quantitative and qualitative study of the morphological and anatomical changes in the needles of common pine growing on the territory of the city of Semey (experimental plots № 1, Silicate Plant area) and pine forest (control plots № 2, Kashtak village, № 3, Borodulikha village).

Needles for study were selected from year to year from the middle part of the crown, from various branches. Studying the length of the needles of the experimental and control plants gives a rather distinct characteristic of the changes that occur under the influence of industrial pollution (Table 2).

T a b l e 2

The growth dynamics of pine needles

№ site	Place of growth	Length of needles by years (cm)					Duration of preservation of needles (years)
		2015	2016	2017	2018	2019	
№ 1 (experimental site)	The area of the Silicate Plant Semey N 50.468442, E 80.212024	–	6,60±0,05	4,14±0,05	4,50±0,04	4,62±0,09	4
№ 2 (control site)	The area of Borodulikha village N 50.7336, E 80.8865	6,12±0,14	6,96±0,11	4,3±0,04	5,7±0,17	5,5±0,18	5
№ 3 (control site)	The area of the village of Kashtak N 50.3983, E 80.6248	6,06±0,19	6,22±0,13	6,72±0,6	6,02±0,14	5,20±0,09	5

A comparative study of the growth dynamics of pine needles showed that the sizes of experimental and control plants differ significantly. The length of the needles of the experimental trees in different years varies from 4.14 to 6.60 cm, while the trees of control area of the Borodulikha village have a length of needles from 4.3 to 6.96 cm ($p < 0.05$) and the second control section, the area of the village Kashtak have a length of needles from 5.20 to 6.72 cm ($p < 0.05$), although the climatic conditions in the growth zones of the control and experimental plants were the same.

Table 2 shows that the inhibition of the growth of needles is directly dependent on the habitat, that is the higher the air pollution, the shorter the length of needles. As for the regions under study as anthropogenic loads, it is possible to observe the duration of survival of needles on a pine tree. Since the needles of model pines were preserved on the experimental site only until 2016, needles were observed mainly in the trees until 2017. In the control areas, needles were preserved for up to 5 years. Some pines could be found needles in 2015. The fall of needles also shows the bio indication properties of pine.

Conclusions

Thus, a fatal decrease in the growth of shoots and needles in the conditions of the Semipalatinsk region is observed in 2015–2019.

An analysis of the presented indicators confirms the response of individuals of common pine to anthropogenic pollution: with an increase in the degree of anthropogenic load, the number of needles on the shoot decreases with a decrease in the length of the shoot itself and the length of the needles.

Based on these data, we can talk about the presence of morphometric limits of pine viability. Here, it is necessary to indicate that viability can be identified at different levels of the plant organism. However, we single out the morphological limit since the actual complex of physiological reactions of the plant usually finds its total expression in the actual growth rate, a certain orientation of which is ensured primarily by changing external conditions.

Thus, it can be seen from the obtained data that the annual growth of shoots and pine needles in the conditions of gas pollution in the city have not yet completely lost their ability to respond to changes in external conditions. Obviously, if we take the path of reducing harmful emissions, then a certain part of the pine stands can still be preserved. Conversely, if the level of pollution increases, urban pine plantations will die, certain sections of pine forests located near the city, within a radius of 20 km, may suffer, since the strongest impact of technogenic pollution on forest stands occurs on annual growth. Deterioration in the state of annual growth of shoot and pine needles is a sign of instability.

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Б.З. Елькенова, Р.Р. Бейсенова, Н.Ш. Карипбаева, В.В. Полевик

Ертіс бойындағы Семей өңіріндегі кәдімгі қарағайдың өсуі мен дамуына атмосфералық ластанудың әсері

Кәдімгі қарағайдың (*Pinus sylvestris* L.) кең таралу аймағы, оның әртүрлі климаттық аймақтарда және экологиялық жағдайларда өсуі, оның морфологиялық айырмашылықтардағы өзгерістерге алып келді. Зерттеу объектісіне Ертіс бойындағы Семей өңіріндегі кәдімгі қарағайдың (*Pinus sylvestris* L.) тізбекті қарағай популяциясы алынған. Мақалада әртүрлі газдануы жағдайында өсетін кәдімгі қарағайдың жылдық өсу көрсеткіштерінің динамикасы туралы деректер келтірілген. Бақылау учаскесін қоса алғанда, үш сынақ алаңдарында қарағай өсімінің морфометриялық параметрлерін салыстыру жүргізілген. Тәжірибелік учаске Семей қаласының шегінде болды, Силикат зауытының ауданы (тәжірибелік учаске, Семей; N 50.468442, E 80.212024) барынша ластанған деп саналды, екі бақылау учаскесі 35 км (бақылау учаскесі, Каштак ауылы ауданы, N 50.3983, E 80.6248) және Бородулиха трассасы бойынша қаладан 60 км (бақылау учаскесі, Бородулиха ауылы ауданы, N 50.7336, E 80.8865) қашықтықта салынды. Жұмыста ағаштарды зерттеудің морфометриялық әдісінің сипаттамасы берілген. Қоршаған ортаға антропогендік әсерін сандық бағалау үшін ағаш өсімдіктерінің өсімі бойынша деректер пайдаланылды, атап айтқанда жылдық өсу мен кәдімгі қарағайдың қылқан жапырақтарының өсу серпінін зерттеу. Осыған байланысты зерттеу үшін әр учаскеде 25–30 жас аралығындағы, биіктігі 6–9 метр, d 24–36 модельді он қарағай таңдап алынды. Тәжірибелік және бақылау өсімдіктерінің қылқандарының ұзындығын зерттеу өнеркәсіптік ластанудың әсерінен пайда болатын өзгерістердің айқын сипаттамасын берді. Сондай-ақ, Ертіс өңірінде өсетін кәдімгі қарағай үшін өсудің басталу, аяқталу мерзімдері және көрінетін өсімнің ұзақтығы анықталды.

Кілт сөздер: кәдімгі қарағай, өсім, діңгек, өркен, өсу мерзімі, сызықтық және радиалды өсім, қылқан, морфометриялық әдіс.

Б.З. Елькенова, Р.Р. Бейсенова, Н.Ш. Карипбаева, В.В. Полевик

Влияние загрязнения атмосферы на рост и развитие сосны обыкновенной в условиях Прииртышья Семипалатинского региона

Широкий ареал сосны обыкновенной (*Pinus sylvestris* L.), произрастание её в разных климатических зонах и экологических условиях привели к изменениям в морфологических отличиях. Объектом изучения является ленточно-боровая популяция сосны обыкновенной *Pinus sylvestris* L. в пределах Прииртышья Семипалатинского региона. В статье приведены данные о динамике роста годичных побегов сосны обыкновенной в условиях различной загазованности воздуха. Проведено сравнение морфометрических параметров прироста побегов сосны на трех пробных площадях, включая контрольный участок. Опытный участок находился в черте города Семея, в районе Силикатного завода (опытный участок, Семей; N 50.468442, E 80.212024), который считается наиболее загрязненным; два контрольных участка были заложены на расстоянии 35 км (контрольный участок, район с. Каштак, N 50.3983, E 80.6248) и 60 км от города по Бородулихинской трассе (контрольный участок, район с. Бородулиха, N 50.7336, E 80.8865). В данной работе дано описание морфометрического метода исследования деревьев. Для

количественных оценок антропогенных воздействий на окружающую среду использованы данные по приросту древесных растений, а именно: изучение динамики роста годичных побегов и хвои сосны обыкновенной. Исходя из этого, для исследования были выбраны 10 модельных сосен на каждом участке, в возрасте 25–30 лет, высотой 6–9 м, диаметром 24–36 см. Изучение длины хвои опытных и контрольных растений дало отчетливую характеристику изменений, возникающих под влиянием промышленного загрязнения. Также для сосны обыкновенной, растущей в Прииртышье, определили сроки начала, окончания продолжительности видимого прироста.

Ключевые слова: сосна обыкновенная, побеги, ствол, скелетные корни, периодичность роста, линейный и радиальный прирост, морфометрический метод.

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