

Health Condition of Scots Pine (*Pinus sylvestris* L.) Growing at Different Distances from Highway "Vilnius-Kaunas"

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396 Scots pine (*Pinus sylvestris* L.) trees growing at the highway sides were investigated. The monitoring parameters (state of tree tops, amount of dry branches, crown defoliation and foliage discolouration, needle retention etc.) were evaluated by using the international forest monitoring methods (Manual on methods..., 1994).

The results illustrate that pine trees growing at the farthest distance (450-500 metres) from the highway have the best health condition (mean crown defoliation 24.8±2.2%) as compared with pines growing closest to highway (defoliation 42.9±1.5%). Amount of dead branches depends on the distance from the highway as follows: at the sample plots (SP) of monitoring closest to the highway – 28.3±1.2%, furthest – 13.7±1.8%. State of pine tops is good - at all SP more than 80% of the healthy tree tops has been estimated.

Key words: Scots pine, health condition, morphological parameters, highway.

Introduction

Transport pollution - the largest source of pollutants in Lithuania - is gradually increasing. The largest share of traffic emission is comprised by carbon monoxide (CO) - 258 thou. tons, hydrocarbonates (C_xH_x) - 60 thou. tons, nitrogen oxides (NO_x) - 36 thou. tons and sulphur dioxide (SO₂) - 5.5 thou. tons. Cars tires and other parts wearing out release about 2.4 thou. tons of hard particles (Baltrėnas et. al., 1996) to the environment.

Roadside plantings accumulate pollutants at roadside and prevent their further distribution. Conifer trees are very sensitive to atmospheric pollution; therefore their ecological state can indicate the influence of pollution on the environment. Crowns of trees have contact area with the atmosphere several times bigger than other plants. The crown's filter transfers pollutants five or six times more effectively than other vegetation.

Trees that grow as forest belts absorb carbon monoxide, sulphur dioxide and other harmful substances. They also accumulate heavy metals that are found in motor transport emissions. Even 3-5 metres of pro-

tective road plantings collect and accumulate about 40-60% of lead and heavy metals from transport emission (Armolaitis, Bartkevičius, 1996).

The landscape and height of roadbed influence the distribution of pollutants at the roadsides. When the height of the roadbed is 0.5-1.2 metres, the largest part of transport emissions fall out at the distance of 10-25 metres from the roadsides. When the roadbed is 1.2-1.5 metres, the largest share of pollutants falls out at the distance of 20-30 metres, although the concentration of pollutants at the distance of 10-20 metres from the waysides is also high. If the level of the road driving part is close to the level of surroundings, then moving away from the roadside the concentration of transport pollutants evenly diminishes (Marone, 1989).

Forests at roadsides serve as cleaning equipment and are gathering pollutants, which in open fields distribute in wide areas. The state of the roadside plantings has not been widely investigated; therefore the Scots pines (*Pinus sylvestris* L.) growing at the sides of the highway were chosen as the object of this investigation.

Material and methods

The aim of investigation is to estimate the health condition of Scots pine (*Pinus sylvestris* L.) trees growing at different distances from the highway "Vilnius-Kaunas" according to the main forest monitoring parameters (crown defoliation, foliage discolouration, the state of tree tops, the amount of dead branches). The following studies were conducted: choosing the object of study; gathering experimental information; estimating the health condition of pines according to their crown defoliation and foliage discolouration, state of the tree tops and the amount of dead branches in the crowns; estimating of the influence of transport pollution on pine tree growth.

The sample plots (SP) were selected in forest ecosystems at roadsides in the 60-70-year-old pine stands of 0.7-0.8 stocking level (*Pinetum vaccinio-myrtillosum* forest type; Nb habitat) at different distances from the roadbed (10-20; 50-100; 150-200; 250-300; 350-400 and 450-500 metres). Each SP was distributed into 6 assessment subplots (AS) with 6 sample trees in each of them. The sample trees in each AS were situated on one line parallel to the highway. The total number of SP is 11, the total number of AS - 66, and that of sample trees - 396. All sample trees from the upper part of the canopy belonging to I-III Kraft classes and situated closest to the subplot centre were chosen.

Monitoring of Scots pine has been conducted in the summer seasons of 1998 and 1999. The end of July and the beginning of August present the most suitable time for forest monitoring (Hanish, Kilz, 1990). Monitoring parameters (state of tree tops, the amount of dead branches, crown defoliation, foliage discolouration and needle retention) were evaluated using the international forest monitoring methods (Manual on methods..., 1994).

The most important tree health condition indicators are crown defoliation and foliage discolouration.

Crown defoliation is not only the loss of the existing foliage (the natural fall of leaves during autumn is not considered), but also that part of the foliage which is possible to form in normal conditions, but did not form in existing ones. In other words, defoliation means the loss of compared to the reference tree, which has full foliage (Manual on methods..., 1994). The reference tree usually is the tree of the same growth, biosocial class as the sample tree, belongs to the same type of branching, grows in the vicinity of the sample tree. The photo of the reference tree corresponding to a sample tree according to special atlases can be used. We used the special atlases with reference tree's photo (Muller, Stierlin, 1990).

Crown defoliation is generally estimated in 5 percentage classes. Defoliation of the whole crown and of the upper third of the crown is estimated.

The sample trees were divided into five classes according to their crown defoliation degree: 0 class - conditionally healthy trees (defoliation less or equal to 10%); 1st class - slightly defoliated trees (11-25%); 2nd class - moderately defoliated trees (26-60%); 3rd class - severely defoliated trees (61-99%); 4th class - dead trees (defoliation 100%).

Foliage discolouration - one of the main monitoring parameters - shows a part of needles or leaves (%), which have changed the colour due to negative impact of external environmental factors. Sample trees are divided into 4 discolouration classes: 0 class - without foliage changes in colour (discolouration up to 10%); 1st - slight discolouration (11-25% of foliage has a changed colour); 2nd - moderate discolouration (26-60%); 3rd - severe discolouration, when over 60% of the foliage has no natural colour.

Severe crown defoliation and foliage discolouration show the negative influence of environmental impact on a tree and indicate their damage (Manual on methods..., 1994).

Condition of tree top has been scored as follows: 0 - top is healthy; 1 - completely broken; 2 - damaged; 3 - dead.

The amount of dead branches in the crown was generally estimated in 5 percentage classes. Dead branches below a live crown are not included. Classes of dead branches are the following: 0 - up to 15%, 1 - 16- 30%, 2 - 31- 50%, 3 - over 50% of dead branches.

The average needle retention of pine is indicated visually at 0.1 year accuracy. For evaluating of needle retention, 3-4 model branches in the upper one third of the crown were selected. Age of terminal shoots containing all needles and the ratio of length of the last (the oldest) shoot with the remaining needles are evaluated with the help of binocular.

When crown defoliation is higher than 10%, the crown defoliation types are defined for each sample tree. The following crown defoliation types were defined: 1 - top; 2 - under the top; 3 - base; 4 - peripheral 5 - inner; 6 - uniform and 7 - window (Ītēčķ+žņ, 1996).

Results

The investigation has indicated that trees growing at the closest distance from the highway were most defoliated comparing with trees growing at other distances.

Distribution of sample trees according to classes of crown defoliation is shown in Figure 1. Even 48%

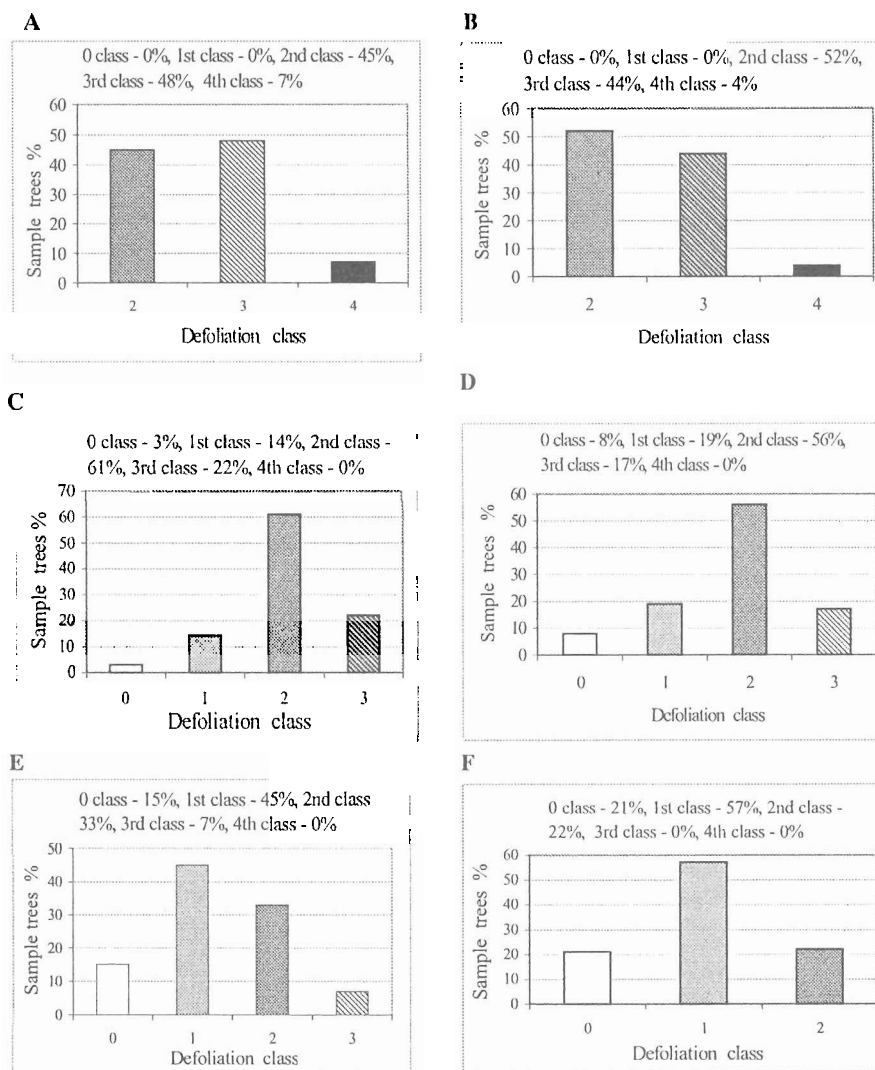


Figure 1. Distribution of sample pine trees (%) growing at different distances from highway “Vilnius – Kaunas” according to classes of crown defoliation: A - 10-20 metres; B - 50-100 metres; C - 150-200 metres; D - 250-300 metres; E - 350-400 metres; F - 450-500 metres

of sample trees growing at the closest distance from the highway are severely damaged (3rd class of defoliation). 45% of the sample trees belonged to the 2nd class of defoliation. Only 7% of dead trees (defoliation 100%) were indicated here. Healthy trees that can indicate the good environment state were not found here. Health condition of pines growing at the distance of 50-100 metres from the highway was slightly better than of these growing at 10-20 metres. At the latter distance the greatest part (52%) of the examined pines were moderately defoliated (2nd class), severely defoliated trees whose crown defoliation reached 61-99% comprised 44% and only 4% of the examined trees were mostly defoliated (4th class of defoliation). Conditionally healthy (defoliation up to 10%) trees were not found at this distance. Health condition of trees at the distances of 150-200 and 250-300 metres from the highway is gradually improving. At the latter distances conditionally healthy trees constitute 3% and 8%; slightly defoliated ones – 14% and 19% of sample

trees; even 61% and 56% are moderately defoliated; 22% and 17% of the sample trees reveal severe defoliation. At the distance of 350-400 metres only 7% of sample pine trees are severely, 33% - moderately, 45% - slightly defoliated and 15% are conditionally healthy. Health condition of pines at the farthest distance (450-500 metres) from the roadbed is best.

The mean crown defoliation of assessed trees at 10-20 metres from the highway reaches $42.9 \pm 1.5\%$. With increasing distance from the roadside, defoliation decreases: at the distance of 50-100 metres the mean defoliation of sample pine trees reaches $39.2 \pm 2.3\%$, at 150-200 metres distance – $36.7 \pm 1.7\%$, at 250-300 metres – $33.7 \pm 2.2\%$, at 350-400 metres – $26.7 \pm 2.4\%$ and at 450-500 metres distance from the highway the crown defoliation degree is lowest - only $24.8 \pm 2.2\%$ (Fig. 2).

Changes of tree foliage colour due to the surplus or lack of some elements (nitrogen, potassium, magnesium and etc.) high concentrations of atmospheric pollution, impact of fungal disease (Taylor et al, 1991),

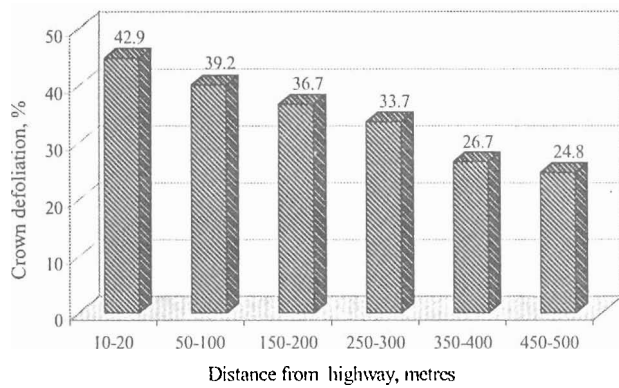


Figure 2. Mean crown defoliation (%) of Scots pine trees growing at different distances from the highway

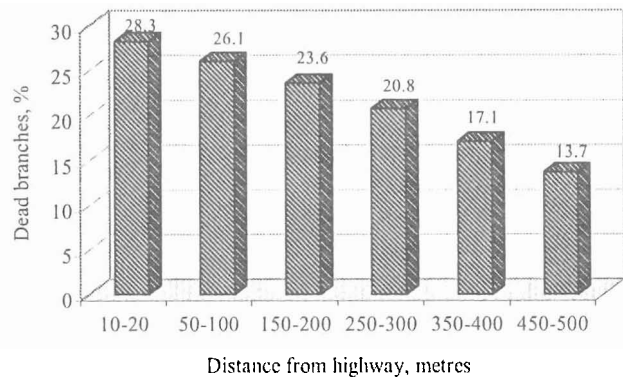


Figure 3. The average amount of dead branches (%) of Scots pine trees at different distances from the highway

droughts (Innes, Boswell, 1991) and other reasons are widely known and spread in some countries of West Europe. Discolouration of Scots pine in Lithuanian forest ecosystems is not common (Ozolinčius, Stakėnas, 1999).

According to the results of our investigation, at all distances from the roadbed pine trees of 0 discolouration class (discolouration up to 10%) predominate. At the closest distance from highway Scots pine trees of 0 discolouration class make up the greatest part (even 51%) of sample trees; 1st class of discolouration (discolouration 11-25%) has been estimated for 49% of sample trees. At the farthest distance (450-500 metres) even 89% of the examined pines are without symptoms of foliage discolouration, slight foliage discolouration has been estimated for 11% of sample pines. As the distance increases foliage discolouration becomes lower (Table 1).

Table 1. Distribution of sample tree (%) according to classes of foliage discolouration and amount of dead branches

Distance from highway, metres	Number of sample trees	Discolouration class				Dead branches %			
		0	1	2	3	0-15	16-30	31-50	over 50
10-20	66	0	1	2	3	9	35	56	0
50-100	66	51	49	0	0	10	41	49	0
150-200	66	64	36	0	0	22	51	27	0
250-300	66	75	25	0	0	30	50	20	0
350-400	66	80	20	0	0	36	53	11	0
450-500	66	89	11	0	0	46	32	22	0

Our research has demonstrated that the largest amount of dead branches is characteristic of Scots pines growing closest (10-20 metres and 50-100 metres) to the roadbed. The trees at the farthest distance from the highway have the least amount of dead branches. With increasing distance from the roadside the amount of dead branches diminishes (see Table 1).

Figure 3 shows the mean amount of dead branches as the distance changes as follows: 10-20 meters – 28.3±1.2% of dead branches, 50-100 metres – 26.1±1.9%, 150-200 metres – 23.6±1.5%, 250-300 metres

– 20.8±1.2%, 350-400 metres – 17.1±0.9%, 450-500 metres – 13.7±1.8%. As presented data illustrate, the assessed pines, growing at the closest distance (10-20 metres) have the largest amount of dead branches and at the farthest distance (450-500 metres) from the highway – the least one.

It must be noted that the state of investigated Scots pine tree tops is good independent of the distance from the highway. More than 80% of the healthy tree tops in each SP have been observed.

The retention of coniferous needle is an important indicator of tree health condition and environmental state assessment. Damaged trees usually loose their old needles sooner than healthy ones. The trees growing in optimal environmental conditions have longer retention of needle. The standard retention of Scots pine needles that indicate the optimal tree growth conditions in Lithuanian forests without the local atmospheric pollution is 4 years. It serves us as the control. Short needle age indicates unfavourable growth conditions.

According to the results of our study the mean retention of sample pine needles at the closest distances (at 10-20 and 50-100 metres) from the highway is 2.0±0.09 and 2.0±0.07 years, respectively. At further distances from the highway it has increased: at 150-200 metres - 2.4±0.08, at 250-300 metres - 2.5±0.07, at 350-400 metres - 3.0±0.05, at 450-500 metres - 3.2±0.07 years (Table 2). In comparison to the control (4 years), this diagnostic test shows the negative impact of traffic pollution on pine growth at the closest distances and negative influence of basic ecoclimatic factors at further distances from the highway.

The type of crown defoliation of the examined Scots pines has been also investigated. The base (3) and uniform (6) crown injury types are dominating in all permanent observation plots. The greatest part of sample pines at the distance up to 300 metres from the roadbed have the base (3) crown defoliation type, the

Distance from highway, metres	Number of sample trees	Mean needle retention, years	Defoliation type						
			1	2	3	4	5	6	7
10-20	66	2.0 ± 0.09	0	9	40	12	5	34	0
50-100	66	2.0 ± 0.07	0	3	42	24	5	26	0
150-200	66	2.4 ± 0.08	2	8	48	3	2	32	5
250-300	66	2.5 ± 0.07	0	2	46	8	2	28	14
350-400	66	3.1 ± 0.05	0	0	40	9	3	38	10
450-500	66	3.2 ± 0.07	0	2	34	11	6	45	0

Table 2. Mean needle retention (years) of Scots pine trees and their distribution (%) according to crown defoliation type

Note: crown defoliation types: 1 – top; 2 – under the top; 3 – base; 4 – peripheral; 5 – inner; 6 – uniform; 7 – window defoliation.

uniform (6) defoliation type prevails among pines that grow at further distances. The top (1) crown defoliation type is not common, under the top (2) and inner (5) – not frequent, window (7) – very seldom for Scots pine trees growing at roadsides (see Table 2).

The base crown defoliation type is estimated in cases when at the bottom part of crowns is by 20% higher than in other parts. As it was noticed (Ozolinčius, 1996), this type of defoliation demonstrates an unspecific morphological response to various types of damages and is common to factors predisposing and inciting tree decline. Uniform crown defoliation type is defined, when defoliation in various tree parts does not differ more than 20%. This defoliation type can cause changes in environmental conditions and is characteristic of tree responses to air pollution, frost, drought and other.

According to the results of our investigation health condition of estimated pines depends on their biosocial class: the examined pines of higher biosocial I and II Kraft classes have lower crown defoliation and less amount of dead branches as compared to the sample trees of the III Kraft class.

Visual assessment of trees' crown condition is comparably fast and simple, but not completely objective, but it is noticed, that the large part of deviation in the defoliation assessment data is not systematic and due to an increase in the number of sample trees the evaluation differences decrease (Dobbertin et al., 1997; Ozolinčius, Stakėnas, 1999).

The monitoring parameters (crown defoliation, foliage discolouration, amount of dead branches in the crowns, needle retention) of Scots pine (*Pinus sylvestris* L.) serve as the natural monitors and indicators to objectively evaluate the influence of all changes taking place in forest ecosystems at roadsides, especially the impact of traffic pollution. As it was noticed by Armolaitis and Bartkevičius (1996), changes in the health condition of roadside conifers are related to the impact of transport emissions, first of all, nitrogen oxides and benzopyrene.

The results have indicated, that differences of assessed morphological parameters of Scots pine trees

of the same Kraft class growing at different distances from the highway are statistically reliable ($P=0.95$). Differences of morphological parameters of sample trees growing at the same distance from the highway are insignificant and statistically unreliable.

Conclusions

1. According to the results of forest monitoring conducted in 1998-1999, it has been estimated, that the mean crown defoliation of Scots pine (*Pinus sylvestris* L.) trees growing in *Pinetum vaccinio-myrtillosum* forests at different distances from the highway "Vilnius-Kaunas" changes. Crown defoliation ($42.9 \pm 1.5\%$) of trees at the closest distance to the highway is found to be highest. With increasing distance from the roadside, defoliation decreases: at the distance of 50-100 metres the mean defoliation of sample pine trees reaches $39.2 \pm 2.3\%$, at 150-200 metres – $36.8 \pm 1.7\%$, at 250-300 metres – $33.7 \pm 2.2\%$, at 350-400 metres – $26.7 \pm 2.4\%$. The lowest crown defoliation ($24.8 \pm 2.2\%$) and the best health condition of pines are at the farthest (450-500 metres) distance from the highway.

2. Discolouration of pine trees at the roadsides of highway "Vilnius-Kaunas" is not a very widespread phenomenon. At all distances from the roadbed pine trees of 0 discolouration class (discolouration up to 10%) are predominating. Nearby the highway pines of this class make up the greatest part (even 51%) of sample trees; 1 class of discolouration (discolouration 11-25%) has been estimated for 49% of sample trees. At the farthest distance (450-500 metres) even 89% of examined pines are without symptoms of foliage discolouration, slight foliage discolouration has been estimated for 11% of sample pines.

3. Health condition of tree tops of the sample trees is generally good. More than 80% of healthy tree tops in each sample plot were estimated.

4. The amount of dead branches – an important morphological indicator of tree health condition – as the distance from the highway changes as follows: 10-20 metres – $28.3 \pm 1.2\%$ of dead branches, 50-100 metres – $26.1 \pm 1.9\%$, 150-200 metres – $23.6 \pm 1.5\%$, 250-300

metres – 20.8±1.2%, 350-400 metres – 17.1±0.9%, 450-500 metres – 13.7±1.8%. The largest amount of dead branches has been estimated at the closest distance from the highway, while least - at the farthest one. It indicates the largest influence of transport emissions on pine state at the closest distance to the highway.

5. The shortest needle retention (2.0±0.09 years) at the closest distances to the highway can indicate unfavourable growth conditions caused by the negative impact of traffic pollution on Scots pine growth.

6. It has been determined that health condition of pines depends on their biosocial class: the examined pines of higher biosocial I and II Kraft classes have lower crown defoliation and the lower amount of dead branches comparing to the sample trees of III Kraft class.

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СОСТОЯНИЕ ЗДОРОВЬЯ СОСНЫ ОБЫКНОВЕННОЙ (*PINUS SYLVESTRIS* L.), ПРОИЗРАСТАЮЩЕЙ НА РАЗЛИЧНОМ РАССТОЯНИИ ОТ АВТОМАГИСТРАЛИ “ВИЛЬНИУС - КАУНАС”

В. Стравинскене

Резюме

Приводятся результаты мониторинга 369 учетных деревьев сосны обыкновенной (*Pinus sylvestris* L.), произрастающей на различном расстоянии от автомагистрали. Руководствуясь методикой экологического мониторинга (Manual on methods..., 1994), определена дефолиация, дехромация кроны, состояние верхушки, % сухих ветвей в кроне, возраст хвои, тип дефолиации кроны учетных деревьев сосны.

Основными индикаторными параметрами состояния здоровья деревьев и их среды послужили дефолиация и дехромация кроны, % сухих ветвей в кроне и возраст хвои.

Исследования показали, что наихудшим состоянием здоровья отличаются деревья, произрастающие на ближайшем расстоянии от автомагистрали. Им характерны наивысшие показатели дефолиации кроны (на 10-20-метровом расстоянии – 42,9±1,5%, на расстоянии 50-100 метров – 39,2±2,3%) и наименьший возраст хвои (2,0 года на 10-20-метровом и 50-100-метровом расстояниях).

По основным показателям мониторинга, в наилучшем состоянии находятся деревья, произрастающие в наибольшем расстоянии от дороги. Средняя дефолиация кроны деревьев на 450-500-метровом расстоянии составляет 24,8±2,2%, верхушки здоровые, сравнительно мало (13,7±1,8%) сухих ветвей (28,3±1,2%), наибольший возраст хвои (3,2 лет), по сравнению с деревьями, растущими вблизи дороги.

На всех учетных расстояниях от автомагистрали доминируют деревья 0-ого класса дехромации (дехромация 0-10%): на ближайшем расстоянии от дороги они составляют 51%, на дальнейшем - 89% общего числа учетных деревьев. Деревья 1-ого класса дехромации (дехромация 11-25%) соответственно составляет: на ближайшем расстоянии 49%, на дальнейшем – только 11% общего числа учетных деревьев.

Ключевые слова: сосна обыкновенная, состояние здоровья, морфологические параметры, поддорожья.