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# Features of Growth and Design of Protective Forests Plantings Along Highways of the South of Russia

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**ABSTRACT**

Protective forest plantations along highways are an integral element and one of the important factors of road safety. The main units of such plantings are tree and shrub species, which in turn form a stand capable of performing useful protective functions. The protective forest stands along highways in Southern Russia were studied on the example of the objects that grow along the M-4 Don highway 30 km from Rostov-on-Don. The forest taxation indices of 18 species of tree and shrub species that form linear plantings were studied. The main tree species in the plantings are: Robinia false acacia, lanceolate ash, small-leaved elm, holly maple, three-pronged gledichia. The main shrubs are: svidina blood red and sumac leather. When designing roadside forest stands, great importance should be given to the initial variant of mixing tree and shrub species. It is not allowed to mix the tree species with different life periods in plantings, as this leads to difficulties in carrying out subsequent forestry care. Thus, the participation of black poplar or pyramidal poplar in plantings with the participation of sharp-leaved maple is unacceptable. The life span of woody plants should be in the same period. The conducted research allowed recommending the optimal mixing schemes for the creation of new protective forest plantations along the highways of Southern Russia.

**Keywords:** assortment of woody plants for protective afforestation, forest strips, protective forest stands, highways, landscaping of highways, construction of forest strips, roadside protective plantings.

## INTRODUCTION

The protective forest stands along highways are invaluable. The main element of such plantings is a stand of trees, which in turn is formed from woody and shrubby plants. In the steppe zone of the South of Russia, the main tree species from which forest plantations are created along highways are: robinia false acacia, lanceolate ash, black poplar, pyramidal poplar, petiolate oak, holly maple and others. Often, a part of such spaces involves shrubs, e.g., sumac leather and svidina blood-red. This is primarily due to the implementation of protective forest plantations along highways aesthetic (decorative) function. These shrubs add color to the overall appearance of the plantings in the autumn period due to the difference in the color of the autumn leaves. For example, yellow shades of ash or maple always contrast with the red color of scumpia or svidina.

The knowledge of the growth, development, stability and life span of various tree species and shrubs in the plantings is of great importance for the formation of protective plantings along highways.

The new schemes used to create planted forests are of particular interest. The existing schemes of plantings assume creation of strips of dense designs as the main purpose of strips-snow retention. Depending on the volume of snow transfer ($m^3/m$) in the region, from 4 to 7 rows are designed, consisting of shrubs, low-growing trees and large trees.

## DEVELOPMENT OF GREEN HIGHWAYS

Highways are one of the main elements of the development of cities and inter-settlement territories. The improvement and safety of roads is not only in the quality of coverage and logistics of

connections between localities. Leading scientists involved in the planning and management of urban plantings separately raise questions about the planning of a roadside forest corridor (Kruzhilin, 2018), as a factor in the development of modern cities. Road safety is directly related to the presence of protective forest stands adjacent to the road. In Russia, when designing highways, the standards that take into account the peculiarities of the formation of protective forest plantations have been developed. These are, for example, "Guidelines for the production of surveys and design of forest plantations along highways" and "Industry Road Methodology of ODM 218.011-98" Public roads. Methodological recommendations for greening roads". Taking into account the peculiarities of climatic conditions and the accumulated experience of strip afforestation, it is important to supplement the existing knowledge with information relating to the creation and formation of forest plantations along highways.

In the study of greening of highways, the following research areas are relevant: anti-erosion sand protection, snow protection, noise protection, gas protection, and dust protection. A separate element is the study of the decorative value of roadside plantings. The same directions are also used in the study of forest plantations along railways (Ivonin, 2020).

The main unit that forms a protective plant is a tree or shrub species. Many researchers were engaged in studying the range of plants in relation to roadside plantings, touching upon the issues of productivity and nature protection role (Zdornov, 2018), the state and efficiency of forest plantations (Carreiro, 2008), and studying the impact of man-made pollution on the state of forest strips (Magnoux, 2018). The study of the structure of forest-belt systems allows seeing the development of individual rocks in the future (Balandier, 2006). A similar promising direction is the development of strategies for managing the growth of plantings based on the mechanisms of dynamics and competition of plants within the plantings (Esaulko, 2016). Such approaches develop a methodology for managing the growth processes in areas, including for adaptive and landscape development of territories (Dubenok, 2017).

Roadside plantings carrying not only decorative, but also recreational functions, should be enriched with valuable species, especially coniferous, which are able to provide decorative effect all year round. Along with the decorative effect, coniferous trees are able to effectively reduce the roadside noise all year round, without decreasing the reclamation component of strip plantations (Dubenok, 2016).

As part of the work on the object "Reconstruction with subsequent operation on a paid basis of the M-4 "Don" highway from Moscow through Voronezh, Rostov-on-Don, Krasnodar to Novorossiysk on the section km 1024-km 1091 in the Rostov region". Stage #4. Preparation of the territory for the construction of the M-4 "Don" highway on the section km 1036+823-km 1072+321 (Rostov region, Novocherkassk, Aksaysky district)", the studies of the protective forest plantations along highways were carried out.

The work was carried out in accordance with the resolution of the Administration of the RO No. 819 of 30.08.12 "On approval of the Order of protection of green spaces in settlements of the Rostov region", the order of the Rostoblkompriroda No. 36 of 12.05.2008 "On approval of the Regulations for the production of works on landscaping objects in settlements of the Rostov region".

The total area on which the research was carried out is 31.2 hectares. The main objective of the research was to conduct a tree inventory to obtain an assessment of the state of growing tree and shrub vegetation in the protective forest plantations along highways.

All types of woody vegetation growing on the site were subject to the survey. During the inventory, the following were determined: genus, species and its age, height, trunk diameter at a height of 1.3 m, condition category. The obtained data were recorded in the inventory list.

Binding and drawing of numbered trees and shrubs was carried out to the site. The internal situation on the object (roads, separate structures, buildings, etc.) was used for linking, as well as additional anchor lines. Due to the period of research (active vegetation of plants and their complete foliage) on the object, the viewing area does not exceed 5-7(10) m, in such cases, the Garmin gpsmap 62s GPS navigator device was used to link plants on the ground, which made it possible to determine the location of plants and sites by geographical coordinates. Subsequently, the existing points with known coordinates were plotted on maps using the SAS program. Planet 14121 (the program represents a single interface for loading and processing map material) (Tanyukevich, 2020).

The height of each growing tree was determined by an EV-1pendulum altimeter. A distance

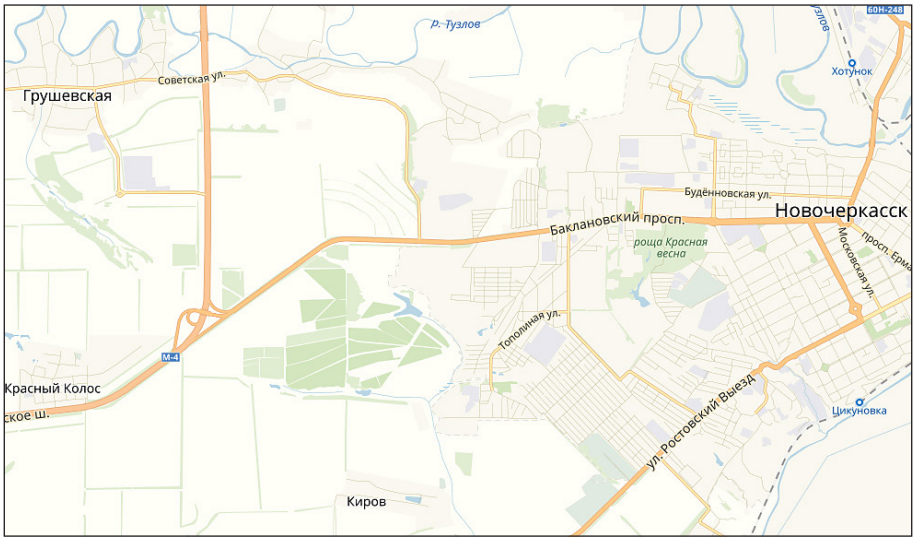


**Figure 1.** Situational diagram of the location of the object of research

equal to the base of the measured plant (10 m) is measured from the tree. The diameter of the trunk at a height of 1.3 m is measured with a fork in two perpendicular directions along one-centimeter steps of thickness.

The condition of each tree was evaluated in accordance with the method of carrying out inventory using the scale:

1) "good" – plants are healthy with a correct, well-developed crown, without significant damage;
2) "satisfactory" – the plants healthy, but with properly developed crown, with a significant, but not life-threatening wounds or injuries, with hollows, etc.;
3) "unsatisfactory" – plants with malfunctioning and poorly developed crown, with considerable damage and injuries, with diseases or infestation of pests, threatening their lives.

The surveyed territory consists of 14 plots of artificial plantations created according to the type of protective roadside forest strips. Plantings of different species composition grow on the presented sites.

The studied plantings were created as protective stands along highways. The terrain of the site is relatively flat, with a slight slope. The type of growing conditions is D1 (dry oak forest).

In all areas, forest litter has formed on the soil surface, the degree of soil sod is from strong to

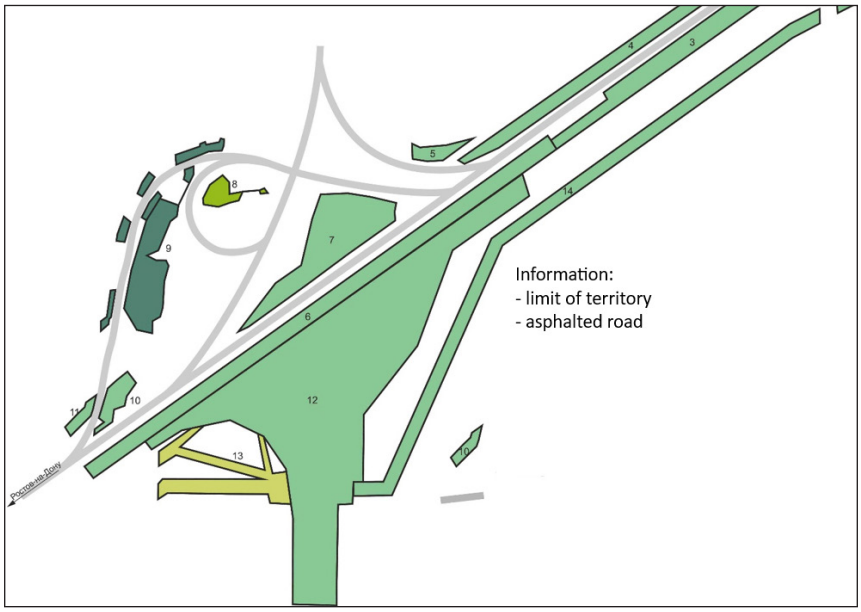


**Figure 2.** Location of research objects

**Table 1.** General characteristics of the sites on the object of research

| Plot number | Area, m² | Area, ha | Number of trees, PCs | Number of shrubs, PCs | Density, PCs/ha |
|---|---|---|---|---|---|
| 1 | 4938 | 0.4938 | 458 | 243 | 928 |
| 2 | 2308 | 0.2308 | 115 | 0 | 498 |
| 3 | 21439 | 2.1439 | 972 | 626 | 453 |
| 4 | 18207 | 1.8207 | 885 | 436 | 486 |
| 5 | 2804 | 0.2804 | 188 | 0 | 670 |
| 6 | 70778 | 7.0778 | 3905 | 573 | 552 |
| 7 | 22227 | 2.2227 | 7317 | 0 | 3292 |
| 8 | 8637 | 0.8637 | 83 | 14 | 96 |
| 9 | 23168 | 2.3168 | 663 | 47 | 286 |
| 10 | 4190 | 0.4190 | 276 | 0 | 659 |
| 11 | 4398 | 0.4398 | 371 | 50 | 844 |
| 12 | 84751 | 8.4751 | 6471 | 1105 | 764 |
| 13 | 12354 series | 1.2354 | 918 | 137 | 743 |
| 14 | 32320 | 3.2320 | 2625 | 291 | 812 |
| Total | 312519 | 31.2519 | 25247 | 3522 | – |

insignificant, self-seeding of maple, ash and other species occurs.

In accordance with the annotated list of rare and endangered plants and fungi of the Rostov region (regional version of the Red Book of Russia, volume 2 – «Plants»), there are no plants included in the specified list on the territory of the object under study.

On each of the 14 sections of forest strips, studies were carried out and the native composition, height, diameters, number of plants on the site and the category of condition were determined. On average, each plantation forms 5 tree and shrub species. The total number of species in the assortment of all plantings is 18 units. The most common of the total amount of plants are lanceolate ash (34%), Robinia false acacia (13%), house plum (12%), small-leaved elm (10%), holly maple (8%), gledichia trifolica (8%), shrubs: svidina and scumpia (12%).

The shrubs svidina blood-red and skumpia kozhevennaya were introduced into the plantings as decorative additions that form contrasts of colors in the autumn period.

The large number of lanceolate ash trees is explained by the abundant reproduction of seeds, which ensures the develipment of undergrowth, both inside and outside the forest strips (Khuzhakhmetova, 2020).

On plot 1, on the generated version of the forest belt, the original mixing were followed by such tree species as Norway maple, black poplar and a honey locust, according to the scheme of mixing:

-G-G-G-G-G-G-G-G-G-
-SV-SV-SV-SV-SV-
-Ko/Yal-Ko/Yal-Ko/Yal-
-Tch-Tch-Tch-Tch-Tch-Tch-
-Ko/Yal-Ko/Yal-Ko/Yal-

Because of this method of introducing black poplar into the plantings, there are difficulties in forestry care within the forest zone.

Tables 2 show the characteristics of trees growing in forest areas. As can be seen from Table 2, all poplar trees have a status category of 3, all trees are completely withered.

On plot 2, there is a plantation created according to the garden type with the placement of home plums 4*4 meters, in order to obtain fruits. By the age of 40, all trees are in good condition due to periodic maintenance.

Plot 3 was originally designed to be planted without the participation of lancet ash according to the scheme:

-G-G-G-G-G-G-G-G-G-
-SV-SV-SV-SV-SV-
-Ko-Ko-Ko-Ko-Ko-
-TCH-TCH-TCH-TCH-TCH-TCH-
-Ko-Ko-Ko-Ko-Ko-

By the age of 50 years, black poplar also completely fell out of the stands.

On sections 4-14, forest strips were created without the participation of black poplar, which is why there is a satisfactory category of trees in plantings.

Due to the large number of open spaces on site 7, self-seeding of lanceolate ash grew en masse,

**Figure 3.** Bushes: a svidina blood-red (left) and sumac leather

**Figure 4.** Self-seeding of lanceolate ash

**Figure 5.** Forest strip on plot 1. Massively dry-shingled Black poplar

**Table 2.** Characteristics of plants in the forest zone on plot 1

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Holly maple | 50 | 13.7 | 32.5 | 178 | 1.4 |
| 2 | Lanceolate ash | 40 | 10.4 | 13.1 | 64 | 1.6 |
| 3 | Svidina blood-red | 20 | 2.5 | 1.5 | 243 | 1.6 |
| 4 | Honey locust treshchalova | 50 | 8.6 | 16.7 | 86 | 1.7 |
| 5 | Black poplar | 50 | 16.0 | 52.0 | 26 | 3.0 |
| 6 | Prickly plum | 20 | 3.5 | 2.0 | 104 | 1.4 |

**Table 3.** Characteristics of plants in the forest zone on plot 2

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Home plum | 40 | 3.5 | 24.0 | 115 | 1.0 |

**Figure 6.** Forest strip on plot 3 (right)

**Table 4.** Characteristics of plants in the forest zone on plot 3

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Holly maple | 50 | 14.6 | 31.1 | 396 | 1.3 |
| 2 | Svidina blood-red | 40 | 2.0 | 2.0 | 297 | 1.4 |
| 3 | Honey locust treshchalova | 20 | 15.5 | 20.6 | 492 | 1.6 |
| 4 | Black poplar | 50 | 16.0 | 48.0 | 84 | 3.0 |
| 5 | Sumac leather | 20 | 3.5 | 2.0 | 329 | 1.4 |

**Table 5.** Characteristics of plants in the forest zone on plot 4

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Holly maple | 50 | 13.0 | 29.9 | 428 | 1.7 |
| 2 | Home plum | 40 | 6.0 | 25.7 | 55 | 1.8 |
| 3 | Lanceolate ash | 20 | 12.5 | 21.3 | 394 | 1.8 |
| 4 | Common apricot | 50 | 11.8 | 23.0 | 8 | 1.8 |
| 5 | Sumac leather | 20 | 3.5 | 2.0 | 436 | 1.6 |

**Table 6.** Characteristics of plants in the forest zone on plot 5

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Common cherry | 30 | 3.8 | 14.6 | 43 | 1.7 |
| 2 | Homemade plum | 30 | 3.6 | 8.3 | 23 | 1.7 |
| 3 | Lanceolate ash | 20 | 4.0 | 8.1 | 46 | 1.2 |
| 4 | Small-leaved elm | 30 | 7.8 | 17.4 | 51 | 1.6 |
| 5 | Pyramidal poplar | 20 | 8.0 | 19.4 | 10 | 1.5 |
| 6 | Common pear | 40 | 5.0 | 17.8 | 12 | 1.8 |
| 7 | Common hawthorn | 15 | 3.5 | 6.0 | 3 | 1.3 |

**Table 7.** Characteristics of plants in the forest zone on plot 6

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Holly maple | 50 | 14.4 | 18.6 | 12.27 | 1.4 |
| 2 | Svidina blood-red | 20 | 2.5 | 2.0 | 255 | 1.3 |
| 3 | Honey locust treshchalova | 50 | 12.6 | 18.1 | 992 | 1.4 |
| 4 | Pyramidal poplar | 30 | 8.0 | 17.0 | 6 | 1.0 |
| 5 | Sumac leather | 20 | 4,0 | 8,0 | 318 | of 1.1 |
| 6 | Lanceolate ash | 30 | 7.1 | 14.6 | 6.90 | 1.3 |
| 7 | Small-leaved elm | 50 | 13.6 | 20.2 | 472 | 1.7 |
| 8 | Robinia false | acacia 50 | 14.7 | 17.8 | 518 | 1.5 |

**Table 8.** Characteristics of plants in the forest zone on plot 7

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Warty birch | 40 | 8.6 | 22.4 | 26 | 1.8 |
| 2 | Crimean pine | 40 | 8.0 | 16.0 | 28 | 1.0 |
| 3 | Lanceolate ash | 20 | 6.0 | 8.0 | 68.25 | 1.1 |
| 4 | Small-leaved elm | 50 | 13.7 | 20.3 | 438 | 1.7 |

**Table 9.** Characteristics of plants in the forest zone on plot 8

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Lanceolate ash | 20 | 7.0 | 8.0 | 32 | 1.3 |
| 2 | Small-leaved elm | 30 | 7.3 | 15.6 | 51 | 1.4 |
| 3 | Svidina blood-red | 10 | 2.5 | 1.5 | 14 | 1.0 |

**Table 10.** Characteristics of plants in the forest zone on plot 9

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Svidina blood-red | 20 | 2.5 | 2.0 | 27 | 1.1 |
| 2 | Sumac leather | 20 | 3.0 | 4.0 | 20 | 1.1 |
| 3 | Lanceolate ash | 30 | 5.0 | 8.0 | 138 | 1.2 |
| 4 | Small leaved elm | 30 | 6.4 | 15.7 | 513 | 1.4 |
| 5 | Common Apricot | 30 | 5.0 | 18.0 | 12 | 1.0 |

which negatively affects the originally conceived appearance of the plantation.

An interesting option for a roadside forest strip is a plantation with the participation of warty birch and Crimean pine. This plant is designed to enhance the aesthetic qualities of the surrounding road area.

Due to the large number of open spaces on site 7, self-seeding of lanceolate ash has grown

**Table 11.** Characteristics of plants in the forest zone on plot 10

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Lanceolate ash | 30 | 6.6 | 106 | 152 | 1.2 |
| 2 | Small leaved elm | 20 | 5.0 | 6.0 | 100 | 1.1 |
| 3 | common Apricot | 30 | 5.0 | 18.0 | 12 | 1.0 |
| 4 | Robinia false | acacia 50 | 8.5 | 23.1 | 11 | 1.7 |
| 5 | Crimean pine | 40 | 11.0 | 28.0 | 1 | 1.0 |

**Table 12.** Characteristics of plants in the forest zone on plot 11

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Holly maple | 50 | 7.2 | 16.5 | 88 | 1.3 |
| 2 | Honey locust treshchalova | 20 | 7.8 | 14.4 | 102 | 1.7 |
| 3 | Sumac leather | 30 | 3.0 | 4.0 | 50 | 1.7 |
| 4 | Lanceolate ash | 30 | 14.2 | 22.0 | 106 | 1.6 |
| 5 | Small-leaved elm | 20 | 3.9 | 6.0 | 32 | 1.3 |
| 6 | Tatar maple | 40 | 6.0 | 13.7 | 43 | 1.8 |

**Table 13.** Characteristics of plants in the forest zone on plot 12

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Lanceolate ash | 30 | 4.2 | 8.2 | 893 | 1.3 |
| 2 | Prickly plum | 20 | 3.5 | 2.0 | 412 | 1.2 |
| 3 | Svidina blood-red | 20 | 2.0 | 2.0 | 1105 | 1.2 |
| 4 | Small-leaved elm | 20 | 6.8 | 15.0 | 872 | 1.2 |
| 5 | Common plum | 30 | 4.0 | 15.9 | 23.42 | 1.3 |
| 6 | Robinia false | acacia 40 | 10.7 | 20.4 | 18.42 | 1.3 |
| 7 | Pyramidal poplar | 40 | 12.7 | 16.7 | 110 | 1.3 |

**Table 14.** Characteristics of plants in the forest zone on plot 13

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Lanceolate ash | 30 | 4.2 | 8.2 | 190 | 1.2 |
| 2 | Prickly plum | 20 | 3.5 | 2.0 | 154 | 1.1 |
| 3 | Svidina blood-red | 20 | 2.0 | 2.0 | 137 | 1.2 |
| 4 | Small-leaved elm | 20 | 6.8 | 15.0 | 99 | 1.2 |
| 5 | Common plum | 40 | 4.0 | 15.9 | 272 | 1.3 |
| 6 | Robinia false | acacia 40 | 10.7 | 20.6 | 203 | 1.3 |

**Table 15.** Characteristics of plants in the forest zone on plot 14

| Item number | Name of the type | Age, years | Height, m | Trunk diameter, cm | Number of plants, PCs | Status category |
|---|---|---|---|---|---|---|
| 1 | Lanceolate ash | 30 | 4.4 | 8.4 | 176 | 1.4 |
| 2 | Prickly plum | 20 | 3.5 | 2.0 | 165 | 1.1 |
| 3 | Svidina blood-red | 20 | 2.0 | 2.0 | 291 | 1.4 |
| 4 | Small-leaved elm | 20 | 6.7 | 14.9 | 322 | 1.4 |
| 5 | Common plum | 30 | 4.0 | 15.9 | 587 | 1.4 |
| 6 | Robinia false | acacia 40 | 7.0 | 12.5 | 10.50 | 1.3 |
| 7 | Common cherry | 40 | 2.5 | 2.0 | 325 | 1.0 |

massively, which negatively affects the originally conceived appearance of the plantation.

From the list of plants with an age of 50 years, the best condition is noted in Gledichia trifoliata and holly maple (the average score of the condition category is 1.5). The Ta-Tarsky maple is also in satisfactory condition, with an average score of 1.8.

**Figure 7**. Trunk of gleditsia tahkoluoto

Such plants as hawthorn, prickly plum, and Crimean pine are characterized by 100% satisfactory condition. Apricot, cherry, elm, gledichia, holly maple, robinia, svidina, scumpia, pyramidal poplar, and ash have a satisfactory condition of about 90% or more.

## CONCLUSIONS

The initial option of mixing tree and shrub species is important in the design of roadside forest stands. It is not permissible to mix the tree species with different life periods in plantings; this leads to the difficulties in carrying out subsequent forestry care.

Long-lasting hard-leaved species, e.g. petiolate oak and lanceolate ash, should be used instead of black poplar in the plantings with the participation of holly maple.

Honey locust should be applied to the plantings the function of which is to limit visiting hours. At the same time, it is allowed to plant gledichia in one row through a distance of 0.7 to 1.5 meters. Its thorns make it extremely difficult for both humans and wild animals to pass through.

The range of woody and shrubby plants in roadside forest stands should be expanded. Thus, red oak has a decorative effect in the autumn period, along with Crimean pine; the introduction of ordinary pine will be successful.

**Figure 8**. Forest strip on plot 7. General view

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