Influence of Graft and Stock on the Stability of Grafted Pinus Sibirica Trees

Iu E Scherba, R N Matveeva, O F Butorova, N P Bratilova and V S Martynov

Reshetnev Siberian State University of Science and Technology, 31 Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russia

E-mail: selekcia@sibgu.ru

Abstract. The growth characteristics of a 30-year-old Pinus sibirica grafted with cuttings from plus trees and a 36-year-old one of different geographical origin on the rootstock of Pinus sylvestris and Pinus sibirica, the results of their studying are presented in the article. The analysis of accretion of grafted components depending on the type, age of the rootstock was done. It has been established that 36-year-old grafted trees using cuttings of Pinus Sibirica of different geographical origin (Altai, Biryusa, Sverdlovsk, Khanty-Mansi) on the Pinus sylvestris tree differ in the growth of scion with rootstock. Ramets with good accretion (without exceeding the diameter of the stem of the scion over the stock) with maximum incompatibility (13.1 cm) were selected. The growth of 30-year-old grafted trees depends on the genotype of plus trees. The most intensive growth of ramet is noted at clone 91/55 in comparison with 100/64 and 94/58. The grafted trees of one clone (91/55) on the Pinus sylvestris had an average graft stem excess of 6.2 cm; there is practically no excess on the Pinus sibirica stock. It is recommended to use the selected specimens without sagging in the places of accretion of grafted components as uterine trees for their further reproduction and the creation of target plantations for the accelerated cultivation and use of industrial wood from Pinus sibirica.

1. Introduction

Wood of Pinus sibirica (Pinus sibirica Du Tour) is light, soft, well-processed, valued for its straightness, beautiful texture and is widely used in the construction of houses, furniture, musical instruments, various handicrafts, in pencil production. Due to the prohibition of cutting of cedar plantations, target plantations are created for the accelerated cultivation of Pinus sibirica to produce valuable wood. Grafting of Pinus sibirica from positive trees certified on stem productivity will make it possible to obtain high-quality wood quickly [1].

Much attention is paid to reproduction of Pinus sibirica due to the fact that this method allows to accelerate not only the growth, but also the beginning of seed production, to obtain increased harvests of seeds for further reproduction of ramets selected on stem productivity [2-5].

The growth of scions in height depends on the individual characteristics of uterine trees, the physiological conformity of the scion and rootstock, environmental conditions [6-10].

When grafting Pinus sibirica, both Pinus sibirica and Pinus sylvestris are used as a stock. A.I. Severova [11] planted Pinus sylvestris, mountain, Rumelian, Weymouth, Pinus sibirica, Korean pine on Pinus sylvestris. Similar experimental studies were also carried out by N.F. Khramova [12], O.P.Olisova and et al. [13], R.N. Matveeva and et al. [14], E.V. Titov [15] and others.
Pinus sylvestris, as a stock for Pinus sibirica, has a number of positive properties: it grows quickly, has low soil requirements, is resistant to climatic conditions, has a developed root system. However, the Pinus sibirica scion in diameter initially catches up with the Pinus sylvestris stock, and later begins to outgrow it in most cases, and it sometimes breaks off in places where the grafted components grow together under the weight of the expanded crown, what leads to plant death [16-19].

The different rate of growth of conductive tissues in the graft and rootstock complicates the passage of nutrients. As a result, the graft gradually outgrows the stock, slowing down the radial growth of the stock [20-23]. The rejection is due to the physiological and biochemical heterogeneity of the stock and graft [24].

In the experiments done by A.I. Severova [11], the successful accretion of the Pinus sibirica graft with the pine stock was observed in 80-90% of cases in the first years. According to G.V. Kuznetsova [25] the percentage of 35-year-old vaccinations with incompatibility ranged from 11 to 95 in different ecotypes.

R.N. Matveeva et al. [26] showed that the Pinus sibirica graft grows much more slowly on the stock of the pine tree than on the Pinus sylvestris, but forms individuals of a better growth of the grafted components, and therefore their durability is noted.

Great influence on the accretion of grafted components has the type and the age of the rootstock. To identify the cause of death of heteroplastic vaccinations, the radial growth of the stock of Pinus sylvestris and the scion of Pinus sibirica with a varying degree of incompatibility was investigated. It has been shown that the interspecific incompatibility of vaccinations can be overcome by selecting the components of the vaccination. In the case of heteroplastic grafts, the phenomenon of anatomical and morphological incompatibility is observed, with different intensity of growth of the graft components by diameter [27].

Analysis of the radial growth and climatic response of heteroplastic grafts of Pinus sibirica and European cedar of three climatypes grafted on Pinus sylvestris stock showed that the radial growth of Pinus sibirica grafts compared to European cedar was 23% higher, which is a consequence of their species characteristics. The radial growth of the Pinus sylvestris depends on the type of graft: the growth of Pinus sylvestris (rootstock for Pinus sibirica) is higher than the growth of control trees by 20% for Surgut climate type and by 15% for Yemelyanovo climate type, while the increment in pine diameter (for European cedar) is 10% less than that of control unvaccinated trees [28].

An active work to create the clonal plantations of various tree species is done abroad. Thus, Li Bailian et al. [29] noted that the increase in the volume of incense pine wood was higher by 12% when rejecting the worst clones on the plantations of the first generation and 30% of the second generation. Clone plantations of Ladanna pine have been created in the USA [30], Calabrian pine, black and Pinus sylvestris in Turkey [31]. Xu Jin et al. [32] studied the variability of Masson pine on the plantation of 140 clones, Y. Moriguchi et al. [35] - Japanese cryptomeria, A.D. Yanchuk et al. [34] studied Sithoi fir tree in Canada, where the variability of wood stocks in depending on clone affiliation was established.

2. Materials and methods

Our research was carried out on the inoculative hybrid and seed plantation of Pinus sibirica in the Karaulny forest area of the Training and Experimental Forestry of SibSU (suburban zone of Krasnoyarsk).

When creating a plantation, cuttings for grafts were harvested from Pinus sibirica plants - offspring of populations of different geographical origin, growing in the arboretum of SibSU, and plus trees certified in the Novosibirsk region. Vaccinations were carried out according to the method of E.P. Prokazina [35] in 1982 in the undergrowth of Pinus sylvestris of 5–10 years old, in 1988 — on 6-year-old seedlings of Pinus sibirica and 20-year-old growth of Pinus sylvestris. The trees were measured in height, diameter of the stem of the stock and scion in the places of accretion, diameter, length of the crown, length of the needles according to generally accepted methods [36]. The obtained results were statistically processed using software packages (Microsoft Office, Excel).

3. Results and discussion
As a result of the research, it was established that the death of grafted trees that have a significant excess of the diameter of the graft trunk over the rootstock occurs as a result of snowbreak, windfall and other factors. It is established that the biometric indicators of grafted trees at 36 years of age range from low to very high levels in accordance with the S.A. Mamaev scale [37]. A very high variation (67%) was noted in excess of the diameter of the scion above the stock (table 1).

Table 1. Variability of indicators of grafted Pinus sibirica trees on Pinus sylvestris.

| Indicator                      | min  | max  | x av. | ±m   | V, % | P, % |
|--------------------------------|------|------|-------|------|------|------|
| Height, m                      | 10.8 | 16.4 | 13.6  | 0.14 | 8.7  | 1.0  |
| Diameter of stock, cm          | 14.0 | 50.6 | 35.5  | 0.92 | 21.7 | 2.7  |
| Diameter of scion, cm          | 20.0 | 64.3 | 42.6  | 1.10 | 21.6 | 2.6  |
| Excess, cm                     | 0.0  | 22.6 | 7.1   | 0.57 | 67.0 | 8.0  |
| Diameter of crone, m           | 3.8  | 9.6  | 6.9   | 0.14 | 17.7 | 2.0  |
| Crown length, m               | 3.8  | 15.5 | 11.9  | 0.29 | 20.7 | 2.4  |
| Needsles length, cm            | 6.5  | 14.0 | 10.0  | 0.19 | 15.8 | 1.9  |

When using cuttings of different geographic origin, it was found that there is a significant variability in excess of the diameter of the scion above the stock diameter (from 0 to 13.1 cm), depending on the geographical origin of the scion and the individual characteristics of uterine trees (figure 1).

![Figure 1. Excess of diameter of the scion above the rootstock in grafted trees of different geographical origin.](image)

Some ramets of Altai and Sverdlovsk origins had the greatest influxes in the places of accretion. The individual characteristics of uterine trees have great importance for the quality of accretion of graft and rootstock. Good fusion was observed in individual trees of tested origins (table 2, figure 2).

Table 2. Biometric indicators of trees characterized by good graft accretion with rootstock.

| Geographic origin | Ramet | Height, m | Diameter of stock, cm | Diameter of scion, cm | Excess, cm | Diameter of crone, m | Live crown length, m | Needles length, cm |
|-------------------|-------|-----------|-----------------------|-----------------------|------------|----------------------|----------------------|-------------------|
| Altai             | 7-11  | 12.8      | 38.8                  | 38.8                  | 0.0        | 7.6                  | 11.7                 | 11.0              |
| Biryusa           | 9-2   | 12.4      | 26.7                  | 26.7                  | 0.0        | 4.8                  | 10.9                 | 12.7              |
| Sverdlovsk        | 14-9  | 14.8      | 40.7                  | 40.7                  | 0.0        | 6.4                  | 13.9                 | 10.3              |
| Khanty-Mansi      | 16-8  | 14.0      | 33.7                  | 33.7                  | 0.0        | 6.0                  | 12.7                 | 12.3              |
|                   | 16-9  | 14.9      | 41.7                  | 41.7                  | 0.0        | 6.6                  | 13.6                 | 8.6               |
Some specimens at the age of 36 years old with a height of 8.3-16.6 m, with the greatest excess of the scion over the stock, have survived (Table 3).

**Table 3.** Ramets of different geographical origin with the greatest excess of diameter of the scion over the stock.

| Geographic origin  | Ramet | Height, m | Diameter, cm | Diameter, cm | excess |
|-------------------|-------|-----------|---------------|---------------|--------|
|                   |       | stock     | scion         | stock         | scion  |
| Altai             | 15-8  | 16.6      | 38.2          | 50.6          | 12.4   |
| Biryusa           | 8-10  | 8.3       | 24.2          | 32.8          | 8.6    |
| Sverdlovsk        | 6-13  | 15.1      | 42.6          | 55.7          | 13.1   |
| Khanty-Mansi      | 4-15  | 13.3      | 39.8          | 44.2          | 4.4    |

During reproduction of Pinus sibirica by grafting in 1988 using cuttings harvested from plus trees No. 91/55, 94/58, 100/64, to 6-year-old Pinus sibirica seedlings, a good accretion of the grafted components was found (Table 4).

**Table 4.** Indicators of 30-year-old grafted trees on the rootstock of 6 years old Pinus sibirica.

| Plus tree | Height, m | Diameter of stem, cm | Diameter of crown, m | Live crown length, m | Needles length, cm |
|-----------|-----------|-----------------------|----------------------|----------------------|--------------------|
|           | stock     | scion                 | excess               |                      |                    |
| 100/64    | 9.1       | 26.9                  | 24.9                 | -2.0                 | 8.7                | 10.1               |
| 94/58     | 8.4       | 28.6                  | 28.6                 | 0.0                  | 6.1                | 8.1                | 10.0               |
| 91/55     | 9.9       | 27.9                  | 28.0                 | 0.1                  | 5.6                | 9.6                | 9.9                |

There is a variability of graft specimens of Pinus sibirica depending on the genotype of uterine trees from which the cuttings were harvested. So, the highest growth figures were in ramets from plus tree № 91/55. The ramet of the tree 94/58 is lagging behind in height by 17.8% in comparison with the clonal progeny of the positive tree 91/55 and by 8.8% - in the tree 100/64. The diameter of the crown had the greatest value in the ramet tree 94/58. K.G. Zatsepina et al. [38] note that when creating clone plantations it is necessary to certify trees, taking into account the establishment of links between biometric indicators and genetically marker features.
Figure 2. Good graft healing with stock (a - graft - Pinus sibirica; b - stock of Pinus sylvestris)

A comparison of the growth rates of 30-year-old grafted trees using a graft of the same genotype (plus tree No. 91/55) on a 20-year old pine tree stock and a 6-year-old Pinus sibirica stock was made (table 5).
Selection of valuable genotypes

The type of stock, growth characteristics of Pinus sylvestris and Pinus sibirica elected grafted into account uterine trees and the ability of cuttings harvested from them for good fusion with the stock resistant to negative factors was established. The selected grafted specimens without sagging in the places of accretion of grafted components are recommended to be used as uterine plants for their further reproduction and creation of target plantations for the accelerated cultivation and use of industrial wood from Pinus sibirica.

4. Conclusion

As a result of the research, the possibility of accelerated cultivation of Pinus sibirica specimens resistant to negative natural factors was established. The type of stock, growth characteristics of uterine trees and the ability of cuttings harvested from them for good fusion with the stock are taken into account. The selected grafted specimens without sagging in the places of accretion of grafted components are recommended to be used as uterine plants for their further reproduction and creation of target plantations for the accelerated cultivation and use of industrial wood from Pinus sibirica.

5. References

[1] Matveeva R N, Butorova O F and Bratilova N P 2003 Poleznuye svoistva i metody rasnozheniya kedra sibirskogo [Useful properties and methods of reproduction of Pinus sibirica] (Krasnoyarsk: SibGTU) p 154

[2] Kolegova N F 1997 Geograficheskiye privivochnuye plantatsii sosny i kedra v Krasnoyarskom lesostepi [Geographical grafting plantations of pine and cedar in the Krasnoyarsk forest-steppe] Geographical cultures and plantations of conifers in Siberia (Novosibirsk: Science) pp 154-166

[3] Martynov V S, Matveeva R N and Butorova O F 2017 Individual’nya izmenchivost radial’nogo prorosta privitykh derev’yev sosny i kedra v Uchebno-opytnom leskhoze SibGU im.M.F.Reshetneva [Individual variability of the radial growth of grafted Pinus sibirica trees on the plantation of the Training and Experimental Forestry of SibSU named after M.F.Reshetnev] Coniferous boreal zone 35 pp 38-41

[4] Tvelenev M V 1975 Razmnnozheniye privivkoy khzyastvenno-tsenykh derev’yev kedra sibirskogo [Reproduction by grafting of economically valuable trees of Pinus sibirica] // Genetics, selection, seed production and introduction of forest species (Moscow: Science) pp 76-82

[5] Titov Ye V 2016 Otbor tsennykh genotypov – klonov kedra sibirskogo na privivochnye plantatsiyakh [Selection of valuable genotypes - clones of Pinus sibirica on grafting plantations] Coniferous boreal zone 5-6 pp 284-289

[6] Rabtsun A S 2013 Metody identifikatsii klonov sosny obyknovennogo na lesosemennykh plantatsiyakh [Methods for the identification of Pinus sylvestris clones on forest seed plantations] MGUL Bulletin. Forest messenger [EE] 3 pp 7-10

[7] Drozdov I I and Bryncev V A 1989 Problems of forming seed base for Siberian cedar (Pinus sibirica Du Tour) in the region of species introduction Proc. Int. Simp. Forest Genetics, Breeding and Physiology of Woody Plants (Moscow: CRIFGaB) pp 205-206

[8] Liu Guogang, Xiao Jie and Yan Lijun 2004 Physiological indicators and regulation of the growth of Korean pine with intragenital graft Dongbei linye daxue xuebao (J. North-East Forest. Univ.) 32 pp 12-13

[9] Mutke S 2005 Cone yield characterization of a stone pine (Pinus pinea L.) clone bank Silvae genet 54 pp 189-197
[10] Schmidting R C 1983 Rootstock influences flowering, growth, and survival of loblolly pine grafts  For. Sci. 29 pp117-124
[11] Severova A I 1958 Vegetativnoye razmnozheniye khvoynykh drevesnykh porod  [Vegetative reproduction of coniferous trees] (Moscow-Leningrad: Goslesbhumizdat) p 143
[12] Khramova N F 1964 Privivki kak metod sozdaniya semennykh uchastkov kedra i kedrovykh sadov v Novosibirskoy oblasti  (Vaccinations as a method of creating seed plots of cedar and cedar gardens in the Novosibirsk region) Renewal and improvement of forests (Novosibirsk: Science) 8 pp 139-144
[13] Olisova O P, Larionova N A and Luzganov A G 1966 Ritm rosta kedra sibirskeogo v geograficheskikh kul’turakh pod Krasnoyarskom (Growth rhythm of Pinus sibirica in geographical cultures near Krasnoyarsk) Proc. report to conf. following the results of n. works for 1965 (Krasnoyarsk: STI) pp 78-79
[14] Matveeva R N 1982 Vegetativnoye razmnozheniye sosny kedrovoj sibirskoy  [Vegetative reproduction of Pinus sibirica] (Krasnoyarsk: KPI) p 72
[15] Titov Ye V 1977 Geograficheskiye privivki kak selektsionnyy priem razviedeniya kedronykh sosen  [Geographical vaccinations as a selection method of cultivation of cedar pines] (Voronezh: CSILGiS) pp 49-52
[16] Dokuchaeva M I 1967 Vegetativnoye razmnozheniye khvoynykh  [Vegetative reproduction of conifers] (Moscow: Lesn. prom-st) p 103
[17] Ibe A A, Chubugina I V, Lozitskaya G M, Dygalo I P, Shaprun E N and Belyaev V V 2012 Otsenka sostoyaniya arkhiva kedrovoj sibirskoy (Pinus sibirica) v Zapadno-Sayanom OLKH  [Estimation of the archive of Siberian cedar pine clones (Pinus sibirica) in the West Sayan EF] Coniferous boreal zone 30 pp 77-79
[18] Kuznetsova G V 1998 Opyt sozdaniya geograficheskoy prvivochnoy plantatsii kedra sibirskeogo v Krasnoyarskoy lesostepi  [The experience of creating a geographic graft plantation of Siberian cedar in the Krasnoyarsk forest-steppe] Forest science 6 pp 63-70
[19] Kuznetsova G V 2016 Privivki kedrovuyh sosen v Krasnoyarskoy lesostepi  [Grafts of Pinus sibirica in the Krasnoyarsk forest-steppe] Intensification of forestry in Russia pp 122-123
[20] Krystev M T and Protas S A 2012 Anatomiya privivki nekotorykh khvoynykh rassteniy  vypolnennoy sposobom vrasshchennya, vypolnennoy sposobom vtvashchennya  (Anatomy of grafting of some coniferous plants, made by splitting) Byul. GBS RAS 198 pp 64-67
[21] Fedotov A V 2000 Osobennosti rosta privitykh klonov kedrovoj sibirskeogo sosen v Ivanteyevskom steppe  [Characteristics of growth of grafted clones of Pinus sibirica in the Ivanteyevsky steppe] Scientific. tr. Mosk. state un-t of forestry 303 pp 191-195
[22] Jayawickrama K J S 1991 Rootstock effects in grafted conifers: A review New fires 5 pp 157-173
[23] Krakowski J and El-Kassaby Y A 2003 Effects of stratification and simulated aging on germination of Douglas-fir seed from a clonal seed orchard Forest Genet. 10 pp 65-70
[24] Titov Ye V 1995 Klonovyye ispytaniya kedrovoj sibirskeogo sosen  [Clone testing of cedar pines] Forestry 6 pp 25–26
[25] Kuznetsova G V and Savva Yu V 2004 K voprosu o mezvidovoy nesovmestimosti privivok kedra sibirskeogo na sosnu obuknovennuyu  [On the issue of interspecific incompatibility of Pinus sibirica inoculations on Pinus sylvestris] Tomsk Bulletin. state un-t of forestry 10 pp 45-46
[26] Matveeva R N, Butorova O F and Shcherba Iu E 2016 Semennoye i vegetativnoye razmnozheniye oselektirovannykh derev’yey sosny kedrovoj sibirskoy  [Seed and vegetative reproduction of selected Pinus sibirica trees] (Krasnoyarsk: SibGTU) p 206
[27] Shcherba Iu E and Grishlova M V 2015 Pokazateli odoletnikh gomoplasticheskikh i heteroplasticheskikh privivok kedrovoj sibirskeogo sosn  [Indicators of annual homoplastic and heteroplastic grafts of Pinus sibirica] Coniferous boreal zone 33 pp 248-252
[28] Darikova Yu A, Vaganov E A, Kuznetsova G V and Grachev A M 2013 Ral’nnyy sostoyaniya arkhiva kedrovoj sibirskeogo sosn  [The experience of creating a geographic graft plantation of Siberian cedar in the Krasnoyarsk forest-steppe] Journal of the Siberian Federal University. Biology 6 pp 3-17
[29] Li Bailian, McKeand Steve and Weir Robert 2000 Impact of forest genetics on sustainable forestry - results from two cycles of loblolly pine breeding in the U.S. J. Sustainable Forest. 10 pp 79-85

[30] McKean S E and Raley (Fred) E M 2000 Interstock effects on strobilus initiation in topgrafted loblolly pine Forest Genet. 7 pp 179-182

[31] Bilir N, Kang K S and Ozturk H 2002 Fertility variation and gene diversity in clonal seed orchards of Pinus brutia, Pinus nigra and Pinus sylvestris in Turkey Silvae genet. 51 pp 112-115

[32] Xu Jin, Wang Zhangrong, Chen Yabin and Qiu Jinqing 2004 Analysis of genetic indicators, signs of seeds and cones, as well as the productivity of clone cones growing in the seed nursery Pinus massoniana Linye kexue = Sci. silv. sin. 40 pp 201-205

[33] Moriguchi Y, Tsuchiya S, Iwata H, Itoo S, Tani N, Taira H and Tsumura Y 2007 Factors influencing male reproductive success in a Cryptomeria japonica seed orchard revealed by microsatellite marker analysis Silvae genet. 56 pp 207-214

[34] Yanchuk A D, Bishir J, Russell J H and Polsson K R 2006 Variation in volume production through clonal deployment: Results from a simulaion model to minimize risk for both a currently known and unknown future pest Silvae genet. 55 pp 25-37

[35] Prokazin Ye P 1960 Novyy metod privivki khvoinykh dlya sozdaniya lesosemennykh uchastkov [A new method of grafting conifers to create forest seed plots] Forestry 5 pp 22-28

[36] Molchanov A A and Smirnov V V 1967 Metodika opredeleniya prirosta drevesnykh rasteni [Method of determining the growth of woody plants] (Moscow: Science) p 27

[37] Mamaev S A 1972 Formy vnutrividovoy izmenchivosti drevesnykh rasteni (na primere Pinaceae na Urale) [Forms of intraspecific variability of woody plants (using the example of Pinaceae in the Urals)] (Moscow: Nauka) p 282

[38] Zatsepina K G, Eckart A K and Tarakanov V V 2012 Genotipirovaniye derev’yev na klonovykh plantatsiyakh khvoynykh lesoobrazuyushikh vidov v Zapadnoy Sibiri [Genotyping of trees on clone plantations of coniferous forest-forming species in Western Siberia] Coniferous boreal zone 30 pp 67-71