ISSN:0975-1459
Journal of Pharmaceutical Sciences and Research
www.jpsr.pharmainfo.in

Resistance of Pure and Mixed Coniferous Forest Stands in the Conditions of the Southern Forest Steppe

Sergey Kabanov, Vasiliy Filatov, Dmitriy Eskov, Evgeniy Samsonov, Galina Zaigralova
Saratov State Vavilov Agrarian University, 410012, Russia, Saratov, Teatralnaya pl., 1

Abstract

The article shows that in the conditions of southern forest steppe of the Volga Upland, high yielding coniferous tree stands, which have been artificially created on long-arable lands, after thinning suffer from annosum root rot. To a greater extent, the disease affects pure pine tree stands.

The following data that characterize the state of pure and mixed coniferous stands are provided: forest inventory indices and forest stand condition, species composition, and the condition of the undergrowth and ground-cover, abundance and condition of the undergrowth. The incompleteness of the age-specific (ontogenetic) spectra of coenopopulations of *Pinus sylvestris* L. and *Larix sibirica* Ledeb. in pure and mixed forest stands has been established. The difference between productivity and stability of pure and mixed coniferous and coniferous and deciduous forest stands has been shown, as well as the effect of pine stands damage by annosum root rot on the species' composition and forest stand renewal in the "decay windows".

For the most productive plantations of coniferous species, it is proposed to track the values of growth intensity, and to reduce growth intensity by timely thinning, if necessary. In order to prevent the wide spread of annosum root rot across coniferous plantations in the region, it is proposed to create pine and larch stands in the future.

Keywords: annosum root rot, productivity, stability, undergrowth, pine, larch, forest stand composition, age structure of the forest stand, pure forest stands, mixed forest stands, growth intensity.

Introduction

Currently, over 10% of all pine plantations in the Saratov region (10.01 out of 80.40 thousand ha) grow in the Bazarno-Karabulaksky district. Pure stands of Scots Pine (*Pinus sylvestris* L.) artificially created 30-50 years ago in the conditions of southern forest steppe of the Volga Upland as protective anti-erosion bands for long-arable lands proved to be unstable [1]. After thinning, foci of annosum root rot (*Heterobasidion annosum* (Fr.) Bref.) appeared. The main reason for "...annosum root rot transition to parasitism and mass spread of the disease..." in pine forests, according to some scientists [2; 3, etc.], "...is the decrease in environmental sustainability of plantings".

The area of weakened pine plantations within the territory of both the region and the Bazarno-Karabulaksky district has been constantly growing [4] in the recent years, and they all are appointed for sanitary felling in large quantities.

The aim of the research consists in finding the difference between the productivity and stability of pure and mixed coniferous plantations; studying the effect of pine stands damage by annosum root rot on the species' composition and forest stand renewal.

Objects and methods of the research

The objects of the research were artificially created pure and mixed stands of Scots Pine, Siberian Larch (*Larix sibirica* Ledeb.), and coniferous plantations with certain deciduous species, in various degrees damaged by annosum root rot, and growing in various forest conditions, where four sample areas were laid (SA12 to 15). For comparison, one sample area (SA11) was laid in a natural pure pine forest stand without signs of damage by annosum root rot.

The plantings were examined according to standard methods [5]. For periodization of the ontogenesis, conventional approaches were used [6; 7]. Symptoms of age-related states were set according to O. V. Smirnova et al. [8]. Latin names of species were given according to S. K. Cherepanov [9].

To assess the relationships among wood species in forest plantations, the following indicators proposed by K. K. Vysotsky [10] had been used:

1) growth intensity of tree species (GII) was the ratio of the average height to the cross- section area of an average taxon diameter;

2) the coefficient of competitive relations (CCR) was the ratio of a tree species' growth intensity with the best growth (and, accordingly, the lowest GII), to the growth intensity of the other one; and

3) the degree of plantings stability (DPS) was the ratio of the actual sum of the coefficients of competitive relations to the maximum possible value.

The analysis used the data from the inventory of five sample areas (SA5-10) by I. E. Khonin [11] and S. A. Kryukov [12], who had previously studied pine plantings in the Bazarno-Karabulaksky forestry (Table 2). Symptoms of annosum root rot spreading in these plantings were absent.

Assessment of forest communities' sustainability was based on the degree of completeness of age specific spectra of forest edificators [13; 14].

Results

Analysis of silvicultural and taxation characteristics of the examined forest stands (Table 1) and the data of the research by I. E. Khonin [11] and S. A. Kryukov [12] (Table 2) shows considerable differences in their growth, productivity and resistance.

Forest stands of various ages were formed in various forest conditions. The most protective forest bands and crops belonged to the higher quality classes (I and Ia). There were also forest stands where the quality class of wood was relatively low (SA11, SA12, SA13), but they all successfully performed protective functions, prevented erosion processes in the adjacent areas, improved the microclimate, and formed the landscape.

The highest growth intensity of coniferous trees was marked at SA15. Pines here had the average height of 22.3 m and the diameter of 26.4 cm, and for larch, these dimensions were 20.5 m and 23.3 cm, respectively. This mixed planting was healthy.

The large average diameter at the age of 75 years was characteristic of natural pine forest stands (SA11) – 26.2 cm. However, the height of pines here was not significant (14.7 m), which indicateed a lower productivity (quality class IV). The forest stand was also quite resistant, and did not show any damage by annosum root rot. At the same time, the highest rate of damage by annosum root rot was noted in case of almost the highest performance (quality class I) in pure pine stands (SA14). Minor damage to pines from the root rot in the form of "small windows" was noted in the mixed pine-and-birch forest stand at SA13, although in terms of growth and productivity, pine was significantly behind pure cultures, where SA14 was laid.

Table 1 – Taxation characteristics of Scots Pine and Siberian Larch in the forest cultures and natural plantings of the Bazarno-Karabulaksky forestry

Sample Area No.	Type and location of planting	Type of forest conditions / age, years	Forest stand composition*	Average diameter, cm	Average height, m	Number of stems, pcs/ha	Reserve, m^3/ha	Quality class	GII of species	GII of planting	CCR	DPS
SA11	Natural planting, top part of the slope, SW exposition, 12-14^0, dark-gray forest sandy loamy soil on sandy loam	$\frac{Ew_1}{75}$	10 S. + Mn. Oc	26.2	14.7	722	309	IV	2.73	2.73	-	-
SA12	Anti-erosion band, middle part of the slope, N-E exposition, 2-3, soil - podzolized sandy loam thin chernozem	$\frac{Ew_1}{48}$	5S 3L 2Ew	24.2 20.8 12.8	16.1 13.8 7.2	447 333 227	177 84 43	II IIIV	3.50 4.06 5.59	4.09	0.62 0.73	0.78
SA13	Forest stands, plain and elevated position, soil is leached medium light loam chernozem on products of gaize weathering	$\frac{S_1}{52}$	8S 2Ew. + L	20.2 23.4	14.5 14.3	958 242	219 64	III III	4.52 3.32	4.28	0.73	0.86
SA14	Forest stands, elevated position, middle part of the slope of the Eastern exposition, 1-2°, soil is dark-gray forest sandy loam with clay interlayers of sandy loam	$\frac{S_2}{52}$	10S	22.6	18.7	896	331	I	4.46	4.46	-	-
SA15	Forest stands, top part of the slope with Northern exposition, soil is leached medium thick light loamy chernozem on products of gaize weathering	$\frac{S_2}{52}$	6L 4S	23.3 26.4	20.5 22.3	549 287	228 156	I Ia	4.81 4.07	4.51	0.85	0.92

Note: *The identification codes adopted for the forest stands: S - Scots Pine (*Pinus sylvestris* L.), L – Siberian larch (*Larix sibirica* Ledeb.), Mn – Norway maple (*Acer platanoides* L.), Oc – common oak (*Quercus robur* L.), Ew - wych elm (*Ulmus laevis* Pall.), Es – Siberian elm (*Ulmus pumila* L.), Ls – small-leaved linden (*Tilia cordata* Mill), Ag – green ash (*Fraxinus lanceolata* Borkh), Aw – wild apple (*Malus sylvestris* Mill).

Table 2 – Some taxation characteristics of Scots Pine and Siberian larch in protective forest bands of the Bazarno-Karabulaksky forestry in the Saratov Region

Sample Area No.	Type and location of the planting	Type of forest conditions / age, years	Forest stand composition	Average diameter, cm	Average height, m	Number of stems, pcs/ha	Reserve, m^3/ha	Quality class	GII of species	GII of planting	CCR	DPS
according to I. E. Khonin [11]												
SA5	Anti-erosion band, the slope with South-East exposition, 1.5-25^0, soil - dark-gray forest sandy loam on sand clay	$\frac{Ew_2}{46}$	10L +S	17.1 18.7	18.9 19.3	1800 40	416.9 10.4	I Ia	8.23 7.03	8.20	0.85	0.93
SA6		$\frac{Ew_1}{46}$	6L 4S	16.0 22.9	17.3 19.9	1470 430	284.6 174.2	I Ia	8.60 4.83	7.75	0.56	0.78
SA7		$\frac{Ew_1}{46}$	10S + L	21.0 16.3	19.0 17.2	1310 100	434.6 19.9	I I	5.48 8.24	5.68	0.67	0.84
SA8		$\frac{Ew_1}{46}$	9S 1L	21.2 15.7	20.9 18.3	1440 190	502.6 34.8	Ia I	5.92 9.45	6.33	0.62	0.81
according to S. A. Kryukov [12]												
SA9	Anti-erosion band, the top part of the Northern slope, soil is podzolized medium thickness medium loamy black soil	$\frac{Oc_{1-2}}{43}$	8L 2S	23.3 23.4	19.6 19.6	540 170	217 71	Ia Ia	4.63 4.56	4.61	0.98	0.96
SA10	Near-draw band, the bottom part of Northern exposition, soil is podzolized medium thickness medium loamy black soil	$\frac{Oc_2}{42}$	10S	20.9	18.7	1050	334	Ia	5.5	5.5	-	-

Table 3 – Characteristics of the undergrowth in coniferous plantings of the Bazarno-Karabulaksky forestry

Sample Area No.	Forest stand composition (origin)	Species composition of the undergrowth (origin)	Number of trees by age states, thousand pieces/ha			
			pl	j	im	v
SA11	10S + Mn, Oc (natural)	S (seed)	0.25	4.25	-	-
		Mn (seed)	-	6.88	8.13	-
		Oc (seed)	-	0.13	-	-
		Ls (vegetative)	-	-	0.13	-
		Oc (vegetative)	-	-	0.25	-
SA12	5S3L2Ew (artificial)	Mn (seed)	-	19.38	13.75	6.88
		Es (vegetative)	0.13	-	0.25	-
		Aw (vegetative)	-	2.5	0.63	-
		Ag (seed)	-	-	-	0.25
SA13	8S2B + L (artificial)	S (seed)	3.5	0.5	-	-
		Mn (seed)	-	-	0.13	-
		Oc (seed)	-	-	0.13	-
SA14	10S (artificial)	S (seed)	21.25	2.0	-	-
		B (seed)	-	0.13	1.88	0.75
		Mn (seed)	-	0.25	0.13	0.63
		Ag (seed)	-	0.13	0.13	-
		Oc (vegetative)	-	0.25	-	-
		Ls (vegetative)	-	-	0.63	0.25
		Es (seed)	-	-	0.25	-
SA15	6L4S (artificial)	S (seed)	0.25	2.0	0.75	-
		Ls (vegetative)	-	-	1.25	0.13
		B (seed)	-	-	0.5	8
		Ew (seed)	-	0.25	0.25	0.13
		Ag (seed)	-	-	0.13	-

The presence of coniferous trees of various ages in the forest stands may be a symptom of their sustainability. Studies have not shown any reliable undergrowth of pine and larch of various ages in most part of the surveyed plantings (Table 3).

Analysis of Table 3 shows that a small number of seedlings (pl) and juvenile plants (j) available in the majority of studied plantations are poorly developed and are in a very depressed condition. Almost complete absence of undergrowth immature (im) and virginile (v) age groups in coniferous forest stands testifies to their low stability. However, in the planting affected by annosum root rot (SA14), the amount of pine undergrowth was significant, it was placed in clumps at the "collapse windows" in the tree canopy, which some authors called "regeneration windows".

V. Z. Gulisashvili [15, p. 237] notes that the regeneration of tree stands of pine and other light-loving species over large areas "...is a result of disasters: forest fires, windfall, attacks of insects, development of fungal diseases, etc." and "... in the window in the parent stand (large) or in the clearings is formed by dying-off of several trees of the top canopy. In this case, full access to light provides the possibility of good growth and development for emerging seedlings and undergrowth".

The presence of numerous pine seedlings in the "collapse windows" (SA14) is an indicator of potential complication of the age structure of pines in forest stands. On most sample areas, healthy young silver birch (*Betula pendula* Roth) and Norway maple (*Acer platanoides* L.) are found. The greatest quantity was also taken into account in the planting affected by annosum root rot (SA14), especially in large-size "windows", where part of the undergrowth had already passed from immature to virginile age status, and some plants - to the young generative state. In the "windows", due to the local improvement of the habitat conditions, the viability of deciduous regrowth increases from low to normal. This is consistent with the studies of other authors [16; 17 et al.].

In some sample areas in the forest cultures and protective plantations, the presence of single trees of common oak (*Quercus robur* L.), wych elm (*Ulmus laevis* Pall), small-leaved linden (*Tilia cordata* Mill.), green ash (*Fraxinus lanceolata* Borkh.), aspen (*Populus tremula* L.) and field-ash (*Sorbus aucuparia* L.) were found, which indicated the tendency towards complication of the species' composition of artificially created plantations with age.

Despite the fact that shrubs were not included into the composition of the surveyed cultures in the planting, the species' composition of the undergrowth was sufficiently diverse. It was represented by Tatarian maple (*Acer tataricum* L.), red elder (*Sambucus racemosa* L.), Siberian pea shrub (*Caragana arborescens* Lam.), dog rose (*Rosa canina* L.), wartybark euonymus (*Euonymus verrucosa* Scop.), golden currant (*Ribes aureum* Pursh), Tatarian honeysuckle (*Lonicera tatarica* L.) and black thorn (*Prunus spinosa* L.). In SA14, the underbrush, same as undergrowth, is largely confined to the windows of pine damage with annosum root rot. Here it is more diverse in the species' composition. In pure tree stands, compared to mixed cultures, the undergrowth is depressed to a greater extent.

The grass cover in the artificial surveyed plantations is represented by typical forest species, and by plants of forest edges and meadows. In addition, a slight presence of plants of open habitats was noted. However, an expressed tendency towards domination of any species in the soil cover was not detected. The height of grass cover in pure pine stands varied between 10 cm and 25 cm, in larch tree stands – between 15 cm and 40 cm, and in mixed stands – between 15 cm and 45 cm.

The protective grass cover in pure tree stands of pine and larch was 20-40 % and 10-40%, respectively, while in mixed stands – 5% to 50%. In certain areas in the natural tree stand (SA11) it reached 100%. Turfing was weak or absent in all sample areas. The general state of the ground cover was satisfactory or weakened. Only in the "windows" of the tree stand affected by annosum root rot (SA14) herbaceous vegetation dramatically increased its vitality.

Our observations show that the process of changing the composition of trees and herbaceous vegetation is more intensive in the "windows". Various tree species are renewed in them, including Scots Pine. However, the wood canopy mainly contains weeping birch (55%), Norway maple, small-leaved linden, and more rarely green ash [18]. This implies that the formation of "regeneration windows" results in increasing heterogeneity of the environment and creating greater patchiness in the tree stand structure. Also, the complication of the composition, vertical and age structure of the tree stand together ensure its resistance.

Discussion

J.G. Puzachenko, [19, p. 125], in analyzing the relationship between the structure and productivity in biogeocenotical systems, has analytically established that "...an increase in species diversity... does not always increase the throughput capacity of the system *(in our case, productivity of tree stands*), but in all cases results in increased resistance". The theoretical statement put forward by the author is confirmed by the results of this research. The indicator of tree stand (of similar age) growth intensity in SA12-15, with increasing the complexity of the natural composition, decreases from 4.51 to 4.09, despite the increase in the number of stems and deterioration of forest conditions. At the same time, almost parallel reduction in the growing stock, i.e. its productivity is observed.

It follows that for increasing the stability of coniferous tree stands, they are to be created mixed from the very beginning. With that, phytocenosis will reduce its productivity, since "...the highest total throughput of the system, as noted by Puzachenko Y. G., will be observed in the case when the dominance of any one species in it is quite clearly expressed, while other species have very small shares" [19].

Validity of this assertion is confirmed by the example of SA5-8, which was laid in the same anti-erosion band. These tree stands were of the same age, but of different composition (Table 2).

In the conditions of subor, pine grows better (quality class Ia) than larch (quality class I), which is naturally associated with a higher exactingness of the latter to soil fertility.

The indicator of pine growth intensity in mixed plantings is always lower than that of larch, but the GII of tree stands in general increases with increasing the number of larches in the composition (from 5.68 to 8.20). With that, the number of surviving trunks per unit of area increases as well. It seems that DPS is also expected to decline, but this does not happen.

It was the highest in SA5 dominated by larch, and the lowest in SA6, where the share of larch was much lower, and was equal to 6 trees. From this it follows that in the conditions of subor:

a) intraspecies' competition among pine trees is more pronounced than among larch trees; and

b) the degree of interspecies' competition (which is characterized by CCR) increases with the increase in the number of larch in the tree stand, but it reduces resistance of the tree stands in general to a lesser extent.

In nemoral conditions, the found regularities are also confirmed, but the GII of the species in pure and mixed natural tree stands was lower than in the subor conditions, and the degree of resistance of mixed tree stands dominated by larch was the highest (0.96). In better conditions, the interspecies' competition of these species greatly increases, but due to higher lability of intracenotic relations, the tree stand still remains very viable, and will be resistant even to considerable fluctuations in the external environmental factors.

Conclusion

Based on the research, the following conclusions and recommendations may be made:

1) due to the incomplete age composition in mixed and pure forest tree stands, pine and larch, having high productivity, feature relatively low total resistance;

2) pure forest stands of pine, compared to mixed ones, and with the natural tree stands are most weakened and damaged by annosum root rot;

3) annosum root rot, reducing the number of trees of the main species in the forest tree stand, locally weakens the intensity of intraspecies' competition, but at the same time, due to increasing the complexity of the composition, vertical and age structure of forest stands, increasing the patchiness, triggers the mechanism of increasing the resistance of the forest biocenosis as a whole;

4) sanitary felling is only appropriate in tree stands severely damaged by annosum root rot, after determining the degree of their resistance in unaffected areas;

5) monitoring the state and resistance of the existing pine forests will allow reducing the growth intensity by felling, and increasing the viability of the main species; and

6) when laying new stands of coniferous trees, it is advisable to make them mixed, with regard to the found regularities.

References

[1] Filatov V. N. and Khonin I. E. Rost i sostoyanie sosnovo-listvennichnih kul'tur i ZLN v lesostepi Saratovskogo Pravoberezh'ya [Growth and state of pine-and-larch crops and protective forest plantings in the steppe of the right bank of the Volga River in the Saratov Region // Fruit growing, seed growing, introduction of woody plants: Proceedings of the 6th International Scientific Conference Krasnoyarsk: LLC Polikom, 2003, pp. 93–95.

[2] Ladeischikova E. I. Ustoichivost sosni protiv kornevoi gubki (itogi kompleksnih issledovanii i perspektivi) [Pine resistance to annosum root rot (results of comprehensive studies and perspectives)]. Forestry and agroforestry, 1980; 60: 41–46.

[3] Rozhkov A. A. and Kozak V. T. Resistance of forests. Moscow: Agropromizdat, 1989, pp. 239

[4] Kozletsov V.V., Kabanov S. V. and Filatov V. N. Sovremennoe sostoyanie sosnovih nasazhdenii B-Karabulakskogo leshoza [Modern state of pine tree-stands in the B-Karabulaksky forestry]. Vavilov readings-2006: Proceedings of the conference dedicated to the 119-th anniversary of Academician N. I. Vavilov. Sections "Environmental engineering", "Forestry and Agroforestry". Saratov: Publishing house of Federal State Educational Institution of Higher Professional Education "Saratov SAU", 2006, pp. 106–111.

[5] Ohiyevskyy V. P. and Khirov A. A. Obsledovanie i issledovanie lesnih kultur. [Surveying and studying forest crops.] Moscow: Forestry, 1964, pp. 50.

[6] Tsenopopulyatsii rastenii: Osnovnie ponyatiya i struktura. [Coenopopulations of plants: Basic concepts and structure]. Moscow: Nauka, 1976, pp. 216.

[7] Tsenopopulyatsii rastenii: Ocherki populyatsionnoi biologii. [Coenopopulations of plants: Essays on population biology]. Moscow: Nauka, 1988, pp. 183.

[8] Chistyakova, A. A., Zaugolnova, L. B., Patinkina, I. V. et al. Diagnozi i klyuchi vozrastnih sostoyanii lesnih rastenii. [Diagnoses and keys of age states of forest plants]. Trees and shrubs: guidance papers for students in biology. Moscow: MGPI, 1989, pp. 102

[9] Cherepanov S. K. Sosudistie rasteniya Rossii i sopredelnykh gosudarstv (v predelah byvshego SSSR). [Vascular plants of Russia and adjacent States (within the former USSR).] St.Petersburg: Mir i Semya-95, 1995, pp. 510.

[10] Vysotsky K. K. Zakonomernosti stroeniya smeshannih drevostoev [Regularities of creating mixed tree stands]. Moscow: Goslesbumizdat, 1962, pp. 181.

[11] Khonin I. E. Growing coniferous species in protective stands, cultures and nurseries with regard to the phytocoenotic approaches in the forest-steppe and steppe of the Lower Volga region: dissertation ... candidate of agricultural sciences. Saratov, 2004, pp. 292.

[12] 12.Kryukov S. A. Viraschivanie hvoinih porod v zaschitnih lesnih nasazhdeniyah Pravoberezh'ya Saratovskoi oblasti [Cultivation of coniferous species in the protection forest stands on the right Bank of the Saratov Region]: abstract. diss. cand. of agricultural sciences. Volgograd: the All-Russian Research Agroforestal Institute, 2001, pp. 18.

[13] Dyrenkov S. A. Struktura i dinamika taezhnih el'nikov. [Structure and dynamics of taiga spruce forests]. Leningrad: Nauka, 1984, pp. 174.

[14] Smirnova O. V., Chistyakova A. A., Popadyuk, R. V. et al. Populyatsionnaya organizatsiya rastitelnogo pokrova lesnih territoriy (na primere shirokolistvennih lesov evropeiskoi chasti SSSR). [Population organization of the vegetation cover in forest territories (on the example of broad-leaved forests in the European part of the USSR).] Pushchino: Dept of Scientific and Technical Information of the Scientific Cengter for Bilogical research of AS of the USSR, 1990, pp. 92.
[15] Gulisashvili V. Z. Vnutrividovie vzaimootnosheniya i regulirovanie chislennosti osobei v rastitelnih soobschestvah [Intraspecies' relationships and regulating the number of species in plant communities]. Modern problems of forestry and forest biogeocenotic. Moscow: Nauka, 1974, pp. 233–245.
[16] Poltinkina I. V. Ontogenesis, number and age composition of field maple cenopopulation in deciduous forests of the European part of the USSR. Bulletin of the Moscow society of naturalists. Department of Biology, 1985; 90(2): 79–88.
[17] Evstigneev O. I. Osobennosti razvitiya shirokolistvennih derevyev pod pologom lesa pri razlichnoi osveschennosti [Peculiarities of broad-leaf trees' development under the forest canopy in various light conditions]. Bot. Journal, 1988; 73(12): 1730-1736.
[18] Kabanov S. V. and Kozletsov V. V. Nekotorie osobennosti okon vozobnovleniya v sosnyakah, povrezhdennih kornevoi gubkoi [Some peculiarities of regeneration windows in pine forests damaged by annosum root rot]. Bulletin of Botanical Garden of the Saratov State University, 2007; 6: 37–41.
[19] Puzachenko Y. G. Sootnoshenie mezhdu strukturoi i produktivnost'yu v biotsenoticheskih sistemah [Relationship between the structure and the productivity in biocenotic systems]. Biological systems in agriculture and forestry. Moscow: Nauka, 1974, pp. 117–126.