чески равен стандартному (1,00). Показатель ударной вязкости – A_{12}, равный 0,68 кгсм/см^2, также выше табличного значения ($A_{табл}$ = 0,40). Удельная характеристика $K = A_{12}/\rho_{12}$, равная $123{,}0 \cdot 10^{-5}$ превышает стандартное значение ($K_{табл} = 90 \cdot 10^{-5}$). У большинства образцов древесины, отобранных в этом насаждении для испытания, значения акустической константы превышали оптимальный параметр равный 12 м^4/кг·с и выше, что подтверждает ее резонансные свойства. Такая древесина используется в производстве музыкальных инструментов и является остродефицитным и дорогим материалом (стоимость 1 м^3 в РФ составляет 100–120 тыс. руб [4], за рубежом около150 тыс. долл. США [5]). Проведенные опытные работы свидетельствуют о возможности ускоренного выращивания резонансной древесиныспособом обрезки ветвей оптимальной интенсивности с одновременным регулированием густоты древостоя. На основании исследований разработанатехнология выращивания резонансной древесины ели европейской, на изобретение получен патент № 2644585.

В заключении следует сказать, что правильно организованное лесное хозяйство в своей основе содержит такое понятие как цикл лесовыращивания, одной из основных задач которого является производство древесины высокого качества. Внедрение технологии обрезки ветвей в практику интенсивного лесохозяйственного производства (включающего регулярные рубки ухода и внесение удобрений) даст возможность получения высококачественного и дорогостоящего крупномерного пиловочного, фанерного сырья и специальных сортиментов, содержащих однородную бессучковую древесину с высокими физико-механическими и акустическими свойствами.

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SEASONAL CHANGES IN XYLOGENESIS AND BIOMASS ACCUMULATION IN THREE CONIFERS SPECIES, GROWING IN EASTERN SIBERIA

The phenology of xylogenesis in the stems of conifer trees with different physico-mechanical properties (Pinus sylvestris L., *Larix sibirica* Ldb., *Picea abovata* L.), *growing in identical exogenous factors in Eastern Siberia, was studied by means of seasonal cambium activity of phloem and xylem cell production and biomass accumulation within xylem cell wall. The each of the species was found to show its own seasonal dynamics the activity of cambium and accumulation of biomass in the course of xylogenesis. The differences in xylogenesis of the conifers are determined by the species-specific features of their metabolism as the reaction on external factors.*
Keywords: *Pinus sylvestris, Larix sibirica, Picea abovata, xylogenesis, cambium activity, xylem, phloem, biomass accumulation.*

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СЕЗОННЫЕ ИЗМЕНЕНИЯ КСИЛОГЕНЕЗА И НАКОПЛЕНИЯ БИОМАССЫ У ТРЕХ ВИДОВ ХВОЙНЫХ ДЕРЕВЬЕВ, ПРОИЗРАСТАЮЩИХ В ВОСТОЧНОЙ СИБИРИ

Фенология ксилогенеза в стволахх хвойных деревьев с различными физико-механическими свойствами (Pinus sylvestris L., Larix sibirica Ldb., Picea abovata L.), произрастающих в условиях идентичных экзогенных факторов в Восточной Сибири, изучена на основе анализа сезонной активности камбия, флоэмы и ксилемы, а также накопления биомассы в клеточной стенке ксилемы. Установлено, что у каждого из видов наблюдается своя сезонная динамика активности камбия и накопления биомассы в процессе ксилогенеза. Различия в ксилогенезе хвойных пород определяются видовыми особенностями их метаболизма, а также реакцией на внешние факторы.
Ключевые слова: *Pinus sylvestris, Larix sibirica, Picea abovata, ксилогенез, активность камбия, ксилема, флоэма, накопление биомассы.*

The process of wood formation (xylogenesis) is the result of the production of cells by cambium, an increase in the radial diameter during expansion growth and the deposition of structural components in cell walls on secondary wall thickening stage [1–3]. The each of the development stage has its own seasonal dynamics in space and in time and reacts autonomously on exogenous (temperature, moisture availability) factors and on endogenous processes in line with physiological changes in the cells on this stage [4, 5]. One of the generalizing studies by the effect of temperature and its limits on conifer xylogenesis growing in cold climate (Europe and Canada) was presented in the paper [6]. Another important factor, which influences xylogenesis, is the accessibility of the moisture. Its deficiency in the cells is reflected in the morphological parameters [7]. There is a critical value of the water potential in tissues, lower than which the radial sizes of cells decrease [8]. The direct effect of water potential on the turgor-dependent expansion of cell walls was shown. The effect of hydrothermal conditions on xylogenesis of different conifer species is mediated by the reaction of metabolism on these conditions, what should affect both the overall process and individual stages of wood formation.

The aim was to study the phenology of xylogenesis in the trunks of conifer trees (*Pinus sylvestris* L., *Larix sibirica* Ldb., *Picea abovata* L.) with different physic-mechanical properties of wood, which grow in the equal environmental conditions of the artificial cultivations in Eastern Siberia. The diameter of the trees was 22, 16 and 14 cm correspondingly.

To study of the kinetics of xylem wood formation the cores were sampled from the tree trunks with the interval 12–15 of the days from the end-April to the middle-October in 2013. The number of xylem and phloem cells, radial and tangential diameters of tracheids and their lumens were measured in 2–3 radial cell rows on two cross-sections of the each core. The data were used to estimate cambium activity (as the number of cambial initial division into xylem and phloem sides [4]), the dynamics of formation of both phloem and xylem (early/late) cells and the dynamics of biomass increment in cell walls. The biomass, accumulated in cell walls, was assessed by cell wall cross-section area, which was calculated using radial and tangential sizes of tracheids, locating in the secondary thickening zone in the period. The difference between cell wall cross-section areas of the subsequent and preceding periods was evaluated as the biomass increment, deposited per each period in the season or per day of the each period.

In the course of xylogenesis the each species showed own seasonal dynamics of both the activity of cambium and accumulation of biomass. The production of phloem cells by cambium began in the stems of pine at the beginning-May, of larch in the middle-May and of spruce in the end-May and continued in pine to the beginning of September, in larch and the spruce trees to second decade-August. Xylem cells formed in pine from middle-May, in larch and spruce from the end-May and to second decade-August correspondingly. Xylem cell production by cambium corresponded to the beginning of new annual wood layer development and occurred with different dynamics in the stems of trees.

The reactivation of cambium producing of phloem and xylem cells in the tree stems of studied species was observed in different periods of the season because of internal reasons. The delay in cambium reactivation in larch stem in comparison with pine occurs because of the delay in growth of needles and shoots, what is important to provide the motion of water along the stem and the creation of water potential gradient in the vertical and horizontal directions. The latter ensures water inflow to the cambium zone what contributes to cell growth by expansion. The reactivation of the cambium in spruce trees in comparison with pine and larch could be detained due to the later warming up of the soil that impeded physiological and metabolic reactions in the cells of xylem tissues.

The differences in the beginning of xylem/phloem cell formation by cambium and in the duration of this process as the reaction of the processes on external factors leaded to the variations in the ratio of phloem/xylem cells in annual rings of studied species. The ratio of phloem/xylem cells, created by cambium in the stems of pine, larch and spruce, in the season was 0.28, 0.44 and 0.21 correspondingly. This shows that in the equal growth conditions the phloem cells were formed more in larch stems than in pine and spruce. The average number of xylem cells in annual wood rings of pine, larch and spruce comprised 68.5, 82.3 and 57.5. The xylem production in larch was more effective in comparison with pine and especially with spruce. The ratio of early/late tracheids in the annual ring structure of pine, larch and spruce was also diverse and comprised 1.4, 1.5 and 1.8 correspondingly. Lager ratio of early/late tracheids in radial rows of spruce can be the result of increased humidity of spruce tissues, what ensured the growth of cells in the radial direction and the formation of the larger number of earlywood tracheids.

The deposition of biomass in cell wall xylem lasted from the end-May to third decade-September. The accumulation of biomass within tracheid walls during cell differentiation in the stems of pine, larch and spruce occurred with the different seasonal dynamics and the diverse intensity in separate periods (Fig.).

The deposition of biomass in the trunks of pine and larch trees occurred irregularly and depended on the external factors. The increase in xylem cell wall area in the season showed three maxims in growth activity in the season (Fig. 1). The decrease in biomass accumulation in the end-June and in the beginning-August was in the first time because of the decrease of moisture reserves in the soil, whereas in second case this was due to very high temperatures, which suppress the deposition of structural components within cells walls [5]. In each of the periods of maximum activity - the end-June, middle-August and especially in September – the biomass increment in annual rings of larch stem exceeded of that deposited in pine stem. In contrast to pine and larch the biomass deposition in annual xylem rings of spruce stem occurred gradually during whole season, descending toward the end August and sharply increasing in the middle of September, when late tracheids completed the development. Some reducing of the biomass accumulation in the trees in second decade-July compared with previous period (the beginning-August), evidently occurred because of high temperature in that time. At the same time the biomass deposition in the spruce stem significantly exceed of that in pine and larch as a result, evidently, of a sufficiency of moisture in spruce stem tissue.

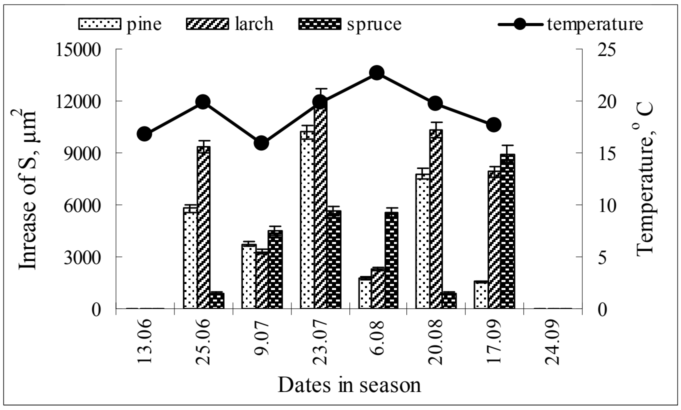

Fig. Dynamics of biomass growth rate in xylem cell walls in the stems of pine, larch and spruce as increment of cell wall cross-section area (S) during the season

The whole biomass, accumulated in tracheid walls during the season was more in the larch, lesser in pine and least of all in spruce. The average content of biomass in the xylem cells of annual rings in the stems of larch exceeded that in pine and spruce in 1.2 times.

The data indicate the higher cambium activity in larch in comparison with pine and especially spruce and the more active metabolic processes, which ensure the biomass accumulation in tracheid walls in larch. The differences in xylogenesis in *Pinus sylvestris* L., *Larix sibirica* Ldb. and *Picea abovata* are by the consequenceof species-specific features of their metabolism and its plasticity in response to changes in the external factors.

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ИССЛЕДОВАНИЕ СВОЙСТВ МЕХАНОАКТИВИРОВАННОЙ ДРЕВЕСНОЙ МАССЫ ДЛЯ ПОЛУЧЕНИЯ ПЛИТ БЕЗ СВЯЗУЮЩЕГО

В работе изучено влияние процессе механоактивации опилок на изменение морфологических характеристик древесных частиц и их аутогезионные свойства при получении материалов без пьезотермических воздействий. В ходе исследований установлено, что с увеличением кратности гидродинамической обработки с эффектом кавитации опилок, происходит повышение доли частиц, представляющих собой фрагменты клеточных стенок. Это позволяют формировать водостойкие плиты с высокими механическими свойствами без использования связующих ипьзотермических воздействий.
Ключевые слова: *древесная масса, активация, опилки, удельная поверхность.*

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STUDY OF THE PROPERTIES OF MECHANICALLY ACTIVATED WOOD PULP FOR THE PRODUCTION OF ADHESIVE-FREE WOOD BOARDS