The Federal Scientific Center on the East Asia Terrestrial Biodiversity FEB RAS, Russian Federation

Northeast Forestry University, P.R. China

Kangwon National University, Republic of Korea

IUFRO
Interconnecting Forests, Science and People

II International Symposium

Korean Pine Biology and Silviculture

PROGRAMME & ABSTRACTS

September 16–25, 2019
Vladivostok
RUSSIA

II International Symposium on Korean Pine Biology and Silviculture

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PROGRAM
&
ABSTRACTS

Chair persons:

Andrey GONTCHAROV (Russia)
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Hailong SHEN (China)

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Venue

The Federal Scientifc Center of the East Asia Terrestrial Biodiversity (159 Stoletiya Avenue, Vladivostok, Russia) hosts the Symposium.

PROGRAMME

The duration of oral talks is supposed to be 25 min plus answers to questions and discussion.

SEPTEMBER 16

09:00 – 10:00 — Registration

10:00 – 10:30 — Opening of the Symposium

10:30 – 11:30 Plenary Lectures

(Moderator: Andrey A. GONTCHAROV)

Aleksandr M. OMELKO, O.N. UKHVATKINA, A.A. ZHMERENETSKY. Korean pine–broadleaved forests of the southern Russian Far East: forest management and current state of research

Hailong SHEN. Research progress and development prospect of Korean pine and broadleaved mixed forest established by approach of "Planting Conifers and Reserving Broadleaved Trees"

11.30 – 13.00 Oral Presentations

(Moderator: Hailong SHEN)

Soyeon KIM, Jungkee CHOI. A theoretical study on the utilization of Korean white pine forest in academic forests

Pavel S. BELYANIN, Nina I. BELYANINA. Appearence of the Korean pine in vegetations of the Russian Far East in the postglacial time

Xingji JIN, Fengri LI, Timo PUKKALA, Lihu DONG New growth models for Korean pine plantations in Northeast China

13:00–14:00 Lunch (Cafeteria)

14.00 – 16.00 Oral Presentations

(Moderator: Jungkee CHOI)

Jae-Mo SONG, Sang-Urk HAN, Jae-Seon YI, Nam Ho KIM, Eun Ju CHEONG The effect of thinning and crown management on cone production and nutritional component of pine nuts

Olga N. UKHVATKINA, A.M. OMELKO, A.A. ZHMERENETSKY Climate-growth relationships reconstructions based on the tree-ring measurements of the *Pinus koraiensis* (Korean pine) trees, Sikhote-Alin Mountain Range, Russian Far East

Weiwei JIA Modeling tree height, crown base height and effective crown height of *Pinus koraiensis* plantation based on knot analysis

Tatiyana P. OREKHOVA. The seeds production and natural renewalof Korean pine in «Ussuriisky» reserve forests

16.15 – Welcome Party (451 Room)

SEPTEMBER 17

9.00 – 10.30 Oral Presentations

(Moderator:)

Aleksandr M. OMELKO, O.N. UKHVATKINA, T.Y. PETRENKO, A.A. ZHMERENETSKY. Disturbance history reconstruction of non-disturbed old-growth Korean pine-broadleaved forest on large permanent sample plot, Sikhote-Alin Mountain Range

Sangyeon HAN, Daesung LEE, Jungkee CHOI. DBH growth of 42 year old orean white pine plantation by first and second thinning

Yinghui ZHAO, Man WANG. Individual tree diameter growth model of Korean pine plantation based on optimized meteorological factor interpolation

10:30-11:00 Coffee break

11.00 – 13.00 Oral Presentations

(Moderator: Alexandr M. OMELKO)

Yeongwan SEO, Daesung LEE, Jungkee CHOI. Comparing optimal rotation age for biomass and volume production of *Pinus koraiensis* and *Pinus densiflora* by thinning intensity in South Korea

Jiacun GU, Zhengquan WANG, Guoqiang GAO,Yanan WANG, Jun QIU. An overview of root functional traits of Korean pine (*Pinus koraiensis*) in northeastern China

Zhang PENG, Yin Dong SHENG, Zhang Jian YING, Ge Wen ZHI, Shen Hai LONG. Effects of fruiting on the traits of different age needles of *Pinus koraiensis*

Zhili LIU, Feng JIANG, Fengri LI, Guangze JIN. Coordination of intra and inter-species leaf traits according to leaf phenology and plant age for three temperate broadleaf species with different shade tolerances

14.30 – 18.00 Bus City Tour

SEPTEMBER 18

9.00 – 10.30 Oral Presentations

(Moderator:)

Fang GAO, Chunxue PENG, Hailong SHEN, Ling YANG, Peng ZHANG. Current results in somatic embryogenesis for *Pinus koraiensis*

Ling YANG, Fang GAO, Chunxue PENG, Hailong SHEN. Optimum programme and influencing factors of embryogenic callus proliferation of *Pinus koraiensis*

Yang GUO, Yihong BAO. Evaluation of simulated *in vitro* release characteristics of three pine nut oil microcapsules

10:30-11:00 Coffee break

11.00 – 13.00 Oral Presentations

(Moderator:)

Xiaowen GE, Jiaojun ZHU, Chunyu ZHU, Pingzhen GAO, Deliang LU, Xiaoyan YANG. The characteristic of Korean pine natural regeneration and its response to species composition in the mixed broadleaved-Korean pine forest

Myunghwan KIM, Dusong CHA, Jungkee CHOI. Analysis of pine wilt disease spread of Korean pine in Chuncheon

Haibo WU, Dongsheng YIN, Peng ZHANG, Hailong SHEN. Effects of girdling and defoliation on cone, branch and leaf growth and carbohydrate content in different organization of *Pinus koraiensis*

Lihu DONG. Evaluation of stand biomass estimation methods for Korean pine in northeast China

13:00–14:00 Lunch (Cafeteria)

14.00 – 16.00 Oral Presentations

(Moderator:)

Lidiya A. SIBIRINA, Galina A. GLADKOVA. Natural Korean pine forests of the National Park «Udege Legend»

Nadezhda V. BUKHAROVA. Aphyllophoroid fungi (Basidiomycota) associated with *Pinus koraiensis* of the Russian Far East

Galina A. GLADKOVA. Soils of Korean pine–broadleaved forests in South Primorye (the V.L. Komarov Ussuriisk State Nature Reserve)

Serafima V. KLYSHEVSKAYA. Microelement composition in the soils of broad-leaved forests in southern Primorye

Poster session

Lixin CHEN. Effects of low molecular weight organic acid on inorganic phosphorus fractions of typical temperate forest soils

16:30 Closing of the Symposium, Farewell Party (Restaurant)

SEPTEMBER 19–26

Field trip to the V.L. Komarov Ussuriisk State Nature Reserve and to Verkhneussuriisky Research Station.

ABSTRACTS

Note about the content of the abstracts

The Organizing and Scientific committees have not made any edits to the content of the abstract. The abstracts are, therefore, presented as they were submitted by the authors.

APPEARENCE OF THE KOREAN PINE IN VEGETATIONS OF THE RUSSIAN FAR EAST IN THE POSTGLACIAL TIME

Pavel S. BELYANIN, Nina I. BELYANINA

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The palynological and chronostratigraphic data obtained in the course of our works gave grounds for dating the Korean pine appearance in the south of the Russian Far East to 11 000–10 500 cal. BP and for reconstructing changes in its proportion in the continental ecosystems of the region through the postglacial time. Fluctuations in the proportion of the Korean pine pollen in the studied pollen assemblages suggest its fast response to climate changes. There is strong evidence that the range of the Korean pine expanded northwards as far as the south of the Russian Far East at the transition from MIS 2 cryochron to the thermochron (the Holocene beginning 11,7 cal. BP). The continental ecosystems of the Pacific landscape zone began to acquire their modern outlook, with the Korean pine becoming their principal constituent in the southern Sikhote-Alin and East Manchuria Mountains. That interval (MIS 2 to MIS 1 transition) corresponds to the time of coniferousbroad leaved forest recovery after the cold epoch had come to its end. The Korean pine continued strengthening its position in the regional vegetation through the Middle Holocene (11,7–4,2 cal. BP), the process being occasionally interrupted with short-term coolings. In the southern Sikhote Alin and East Manchuria Mountains the species became the main element of the coenoses in polydominant forests of complex structure, while in the middle Sikhote Alin it formed a component of mixed forests in association with small-leaved trees, Yezo spruce, Khingan fir and a few broad-leaved species. In the Late Holocene the less stable climatic conditions account for differently directed (mostly from north to south and vice versa) migrations of the Korean pine in the south of the Far East. The range of the species increased in area at the end of the Late Holocene due to an amelioration of natural conditions, its outlines being close to those of today. The natural ecosystems acquired their modern appearance. The species composition of the vegetation, however, was still poorer than that of the Holocene optimum.

APHYLLOPHOROID FUNGI (BASIDIOMYCOTA) ASSOCIATED WITH *PINUS KORAIENSIS* OF THE RUSSIAN FAR EAST

Nadezhda V. BUKHAROVA

Federal Scientific Center of the East Asia Terrestrial Biodiversity FEB RAS, Vladivostok, Russia

Aphyllophoroid fungi play an important role in forest ecosystems, being the main destroyers of wood. They are able to destroy wood at different stages of its decomposition. Some of the aphyllophoroid fungi live on soil and form ectomycorrhiza with tree and shrub species. The pine-broadleaved forests are the most valuable of all the variety of coniferous forests of the Far East. Our work is quite relebant, as there is almost no research on the species diversity of aphyllophoroid fungi associated with *Pinus koraiensis*.

For several decades, Lyubarsky L.V. purposefully studied wood-destroying fungi on various forest-forming species in the south of the Russian Far East, including on *P. koraiensis*. The results are presented in the monograph "Wood-destroying fungi of the Far East" (Lyubarsky, Vasilyeva, 1975), where 25 species of aphyllophoroid fungi on *P. koraiensis* are listed. In addition, five years ago, V.F. Malysheva and co-authors (2014) carried out considerable work on the study of ectomycorrhizal fungal diversity of *P. koraiensis* in the forests of the Central Sikhote-Alin. They identified 27 species of ectomycorrhizal aphyllophoroid fungi associated with *P. koraiensis*.

Our research consisted in viewing literary sources, and herbarium materials (VLA) was studied. In addition, there were own pickings in the pine-broadleaved forests of Primorye Territory (Krasnoarmeiskii district), Khabarovsk Territory (Bolshoi Khekhtsir Reserve), Jewish Autonomous Region (Bastak Reserve). It was found that there are 103 species of aphyllophoroid fungi associated with *P. koraiensis* of the Far East of Russia. Most of the identified fungi belong to the group of xylosaprotrophs, destroying wood at different stages of decomposition: deadwood, fallen and dead tree trunks, stumps, twig (*Phlebiella fibrillosa* (Hallenb.) K.H. Larss. et Hjortstam, P*ostia sericeomollis* (Romell) Jülich, *Pycnoporellus fulgens* (Fr.) Donk, *Fomitopsis cajanderi* (P. Karst.) Kotl. et Pouzar, *F. pinicola* (Sw.) P. Karst., *F. rosea* (Alb. et Schwein.) P. Karst., *Gloeophyllum odoratum* (Wulfen) Imazeki and others). *Cryptoporus volvatus* (Peck) Shear from dead trunks of *P. koraiensis* is listed in Red Data Books of Primorie, Amur and Sakhalin Regions.

Fungi, causing destruction of living trees, are of particular importance. *Phellinus pini* (Brot.) Pilát is the most dangerous pathogenic fungi on *P. koraiensis*. *Albatrellus ovinus* (Schaeff.) Kotl. et Pouzar, *Ramaria aurea* (Schaeff.) Quél., *R. eumorpha* (P. Karst.) Corner, R. stricta (Pers.) Quél., *Piloderma olivaceum* (Parmasto) Hjortstam, *Tomentella botryoides* (Schwein.) Bourdot et Galzin, *Tomentellopsis submollis* (Svrček) Hjortstam and others form mycorrhiza with *P. koraiensis*.

This work contains only preliminary data adout biodiversity aphyllophoroid fungi in pine-broadleaved forests. This study requires further research, including the need to assess the degree of infestation of *P. koraiensis* by fungi.

EFFECTS OF LOW MOLECULAR WEIGHT ORGANIC ACID ON INORGANIC PHOSPHORUS FRACTIONS OF TYPICAL TEMPERATE FOREST SOILS

Lixin CHEN

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This study explored the effects of low-molecular-weight organic acids on the inorganic phosphorus fractions of typical temperate forest soils in order to test the potential of these acids to convert inorganic phosphorus into phosphorus available to plants. The results obtained can provide data for use in the restoration and reconstruction of degraded temperate forest ecosystems, as well as the improvement of soil phosphorus utilization.

The effects of different concentrations (10, 25, 50, and 100 mmol/L) of oxalic acid, citric acid, and acetic acid, as well as a control treatment (CK, distilled water) on inorganic phosphorus in the A layer of soil from four types of typical temperate forest (virgin *Betula costata–Pinus koriensis* forest, natural birch secondary forest, *P. koriensis* plantation, and larch plantation) were studied by using 120-day indoor incubation methods

The three kinds of low-molecular-weight organic acids activated Al-P and Fe-P, and solidified O-P and Ca-P in *P. koriensis* plantation and larch plantation soils, with the effect of the acids ranking oxalic acid > citric acid > acetic acid. Citric acid and oxalic acid reduced the O-P content in natural birch secondary forest, and translated it into other inorganic forms of phosphorus. Overall, after the treatment of the four forest types' soil with low-molecular-weight organic acids, inorganic phosphorus could be transformed into Al-P and Fe-P with high availability, thus improving soil phosphorus supplying capacity to plants. Low-molecular-weight organic acids had significant effects on the change in soil inorganic phosphorus fractions ($P < 0.05$), and the magnitude of the changes ranked Ca-P > Fe-P > Al-P > O-P. Medium and low concentrations had the greatest impact on variation in Al-P, Fe-P, and O-P, and high concentrations had the greatest impact on variation in Ca-P. The treatment time had a significant influence on the change in inorganic phosphorus ($P < 0.05$). The effects on Al-P and Fe-P in all four forest types were enhanced with longer treatment time, and the effects for O-P and Ca-P were diminished by prolonged treatment. All the factors examined had significant interactions with forest type ($P < 0.05$). The transformation of inorganic phosphorus fractions in soil interacted with inorganic phosphorus forms, types of organic acids, the time of culture, acid concentration, and forest type.

The activation of soil phosphorus by organic acids was a slow and continuously dynamic process. Low-molecular-weight organic acids could affect the composition of inorganic phosphorus in the soil, and promote the dissolution of insoluble phosphate, thus improving the availability of soil phosphorus. This study showed that oxalic acid, citric acid, and acetic acid affected soil inorganic phosphorus fractions in four different typical temperate forest types, and improved the availability of inorganic phosphorus fractions in the soil.

EVALUATION OF STAND BIOMASS ESTIMATION METHODS FOR KOREAN PINE IN NORTHEAST CHINA

Lihu DONG

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The information on forest biomass across large geographic areas is commonly obtained from National Forest Continuous Inventory (NFCI). However, the NFCI data of Northeast China, have not been fully utilized and stand biomass equations have been limited or lacking for the region. In this study, a total of 186 permanent sample plots were obtained in Northeast China. We developed three additive systems of stand biomass equations as follows: the first additive system (M-1) used stand variables as the predictors (i.e., stand basal area and average height); the second additive system (M-2) utilized stand volume as the sole predictor; and the third additive system (M-3) included both stand volume and biomass expansion and conversion factors (BCEF) as the predictors. The model coefficients were simultaneously estimated using nonlinear seemingly unrelated regression (NSUR). The heteroscedasticity in model residuals was addressed by applying a unique weight function to each equation. Based on jackknifing residuals, several statistics were used to assess model prediction performance. Finally, we comprehensively evaluated four stand biomass estimation methods (i.e., M-1, M-2, M-3 and constant BCEF (M-4)). Our results indicated: (1) the three additive systems of stand biomass equations showed good model fitting and prediction performance; e.g., the Ra^2 in most of the models were more than 0.80, the mean prediction error was close to 0, the mean absolute error and mean absolute percent error were relatively small; (2) M-3 significantly improved the model fitting and performance; and (3) M-3 provided the most accurate predictions for most of the total and components of stand biomass, followed by M-2, while M-1 and M-4 had relatively poor accuracy for estimating stand biomass. Overall, these additive models can be used to estimate the aboveground and belowground stand biomass for Korean pine in Northeast China, but the selection of the most adequate method depends on the available data and forest type.

CURRENT RESULTS IN SOMATIC EMBRYOGENESIS FOR *PINUS KORAIENSIS*

***Fang GAO*, Chunxue PENG, Hailong SHEN, Ling YANG, Peng ZHANG**

Department of Silviculture, School of Forestry, Northeast Forestry University, Harbin, China

Korean pine (*Pinus koraiensis* Sieb. et Zucc.) is an important economical tree species which produced oil, high-quality timber and nuts (Liang et al. , 2015). It is the dominant and community-constructive species (edificato) in cool-temperate zonal climax forest of mixed Korean pine and broad leaved trees in its focused distribution areas and produces high quality pine timber, nutritious edible nut and other products like turpentine. Especially, Korean pine nut production has become the supporting industry in Northeast China's forest regions because that timber harvest has had stopped for natural Korean pine forest and no timber can harvest in Korean pine plantations currently in China.

Somatic embryogenesis is considered the main way to achieve true rejuvenation in vegetative propagules because somatic embryos develop both embryonic apical and root meristems (Lelu-Walter et al., 2018), Embryogenic callus was the foundation for plant regeneration system of high frequency, and important material of genetic transformation, and quite interesting and provides an ideal system for investigation of the whole process of single cell differentiation as well as the expression of totipotency (Zeng et al., 2007; Yang et al., 2010; Santa-Catarina et al., 2013; Steiner et al., 2016). In the breeding work, the combination of somatic embryogenesis and the cryopreservation of embryogenic callus can realize the large-scale propagation of excellent seed resources (Lelu-Walter et al., 2013; Tret'yakova et al., 2015; Ahn et al., 2017).

At present, a relative high effective *P. koraiensis* SE system has been established by using immature zygotic embryo (ZE), The main results were as follows: (1) explant collection time for *P. koraiensis* SE was at the end of June or at the begging of July, which was strongly depended on the developmental status of ZE that was influenced by stock trees, locating place of cones on stock tree crown and locating place of seeds on cone; (2) good embryogeneric callus could be obtained from suitable explant of immature ZE by DCR medium and supplemented with 2 mg/L NAA + 1.5 mg/L 6-BA; and the embryogeneric callus could be maintained and proliferated well by DCR medium with 0.5 mg/L 2,4-D + 0.1 mg/L 6-BA, the subcullture period should be in 15 days; somatic embryos was obtained but not in ideal quantity and good status; (3) improved embryogenic callus, large quantity somatic pre-embryos and good matured somatic embryos were obtained recently on mLV media. These results would provide scientific support for the establishment of large-scale high-efficiency micropropagation system of the genetic improved materials of *P. koraiensis* via somatic embryogenesis.

THE CHARACTERISTIC OF KOREAN PINE NATURAL REGENERATION AND ITS RESPONSE TO SPECIES COMPOSITION IN THE MIXED BROADLEAVED-KOREAN PINE FOREST

***Xiaowen GE*[1,2], *Jiaojun ZHU*[1,2], *Chunyu ZHU*[1,2], *Pingzhen GAO*[1,2], *Deliang LU*[1,2,3], *Xiaoyan YANG*[4]**

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Korean pine (*Pinus koraiensis*) has difficulty regenerating naturally in the mixed broadleaved-Korean pine forest. Preliminary investigation found that the natural regeneration of Korean pine was significantly influenced by proportion of dominant tree species. Therefore, in order to identify the relationships between Korean pine regeneration and dominant tree species, we set 147 plots (30 m × 30 m) according to the relative basal area of Korean pine (PKp, 0–20%, 20–40%, 40–60%, 60–80% and 80–100%) in Liangshui National Natural Reserve, Fenglin National Natural Reserve, Lushuihe Forestry Bureau and Changbai Mountain National Natural Reserve, and investigated the tree layer (DBH>5 cm) and the regeneration layer of Korean pine (DBH≤5 cm). At first, the regeneration characteristics including abundance, age structure and composition of four areas were compared and analyzed. As for the composition, regeneration layer was divided into younger seedlings (1–3a), elder seedlings (4 –10a) and saplings (>11a). Then redundancy analysis was used to explore the relationships between regeneration layer and environmental variables related to tree species composition, stand structure and site conditions. General linear modeling was also used to examine their effects on abundance of younger seedlings, elder seedlings and saplings.

The results showed that regeneration layer of Korean pine had a quite long age span from one-year-old to sixty-years-old. The age span significantly shortened with the increase of P_{Kp}, reflecting in the decrease of saplings and the increase of younger seedlings. This indicated there was a high mortality rate for regeneration layer in the stands with high P_{Kp}. In different study areas, the PKp had different influence on regeneration layer. Even in the same area, the regeneration density in plots with similar P_{Kp} varied considerably. These indicated there probably were other factors that affected the natural regeneration of Korean pine.

By ordination analysis, density of trees (*Den_tree*), P_{Kp}, elevation (*Ele*), slope aspect (east (*SloAsp.E*) and southwest (*SloAsp.SW*)), mean DBH of trees (*MeanDBH*), slope position (whole slope (*SloPos.Whole*)) and relative basal area of birch (P_B), showed significant association with Korean pine regeneration. Among these factors, stand factor accounted for 26.7% of the variation, site factor accounted for 11.7%, interactions between stand and site factors accounted for 3.44%, and the undetermined factor probably due

to man-made interference and stand spatial structure accounted for 58.1%. Furthermore, in generalized linear models, P_{Kp}, *Ele, SloAsp.E* and *SloPos.Whole* had positive effects on abundance of younger seedlings, while MeanDBH had a negative effect (R^2 = 0.464). *SloAsp.SW, SloPos.Whole* and *Den_tree* had positive effects on elder seedlings (R^2 = 0.374). As for saplings, *Den_tree* and P_B had positive effects while P_{Kp} and *Ele* had negative effects (R^2 = 0.557).

We concluded that the research results could partially provide some forest management guidance for promoting Korean pine regeneration, such as adjusting P_{Kp} in local microenvironment by single-tree selective logging, sowing or planting in suitable site. However, both disturbance history and spatial heterogeneity of regeneration pattern need to be researched further to understand the natural regeneration of Korean pine comprehensively.

SOILS OF KOREAN PINE–BROADLEAVED FORESTS IN SOUTH PRIMORYE (THE V.L. KOMAROV USSURIISK STATE NATURE RESERVE)

Galina A. GLADKOVA

Federal Scientific Center of the East Asia Terrestrial Biodiversity, FEB RAS, Vladivostok

Virgin Korean pine-broad-leaved forests, where the main forest species is Korean pine (*Pinus koraiensis* Siebold et Zucc.), preserved in the main only on the territory of Ussuriisk State Nature Reserve. It is believed that the development of these forests in the Reserve for 500 years was carried out without the impact of strong forest destruction factors. In neighboring countries with Russia (China, North Korea and the Republic of Korea), such forests are mainly replaced by derived groups, as well as the soil under them are strongly transformed under the influence of logging and fires.

Depending on the position in the relief on the territory of the Reserve are distinguished mountain and valley habitats of Korean pine-broad-leaved forests. During the inventory work under the Korean pine-broad-leaved forests we have identified the following types of soil. Type I Burozem (Cambisols): typical, slightly gleic, slightly podzolised and with coarse humus. Type II Dark Burozem (Humic Cambisols): slightly gleic, slightly podzolised. Type III Alluvial Dark Humus soils.

Typical Burozems are formed mainly in the upper or middle parts of the southern mountain slopes (200–300 m a.s.l.) under oak- Korean pine and broad-leaved-needle fir-Korean pine forests.

Slightly gleic Burozems are met on different relief elements: the river terraces, steep peaks and slopes under broad-leaved-needle fir-Korean pine, broad-leaved-needle fir-spruce-Korean pine, and valley Korean pine forests.

Slightly podzolised Burozem often developed on the plateau-like areas and gentle northern slopes, where grow broad-leaved-needle fir-spruce-Korean pine forests.

Coarse-humus Burozems are formed under broad-leaved-needle fir-spruce-Korean pine, broad-leaved-needle fir-Korean pine forests on the western or south-western slopes.

Dark Burozems were met by us only under hornbeam broad-leaved-needle fir-Korean pine forests on the slopes of the southern exposure, 200–250 m a.s.l.

Alluvial Dark Humus soil is formed under the valley forests, where the main forest species are Korean pine, Japanese elm and Manchurian ash.

Humidification conditions, which are a function of climate, relief, stony, etc., are the most important factor determining the growth of woody species, as well as the formation of the variety of soils that we have met in the Reserve. Maximum of soil and forest types is characteristic of moist periodically wet soil moisture regime: Burozems (typical, coarse-humus, slightly gleic), the Dark Burozem (slightly gleic), Burozems on alluvial sediments.

The most demanding to soil moisture and fertility are the valley Korean pine-broad-leaved and broad-leaved-Korean pine-needle fir forests.

In a good number of the test areas in the soil profiles we found wood charcoal in Ah or Bw horizons. This indicates that post-fire recovery changes (usually the final stages) in the Reserve are not that rare, as previously thought. Over the past century, the regenerative change was mostly due to natural catastrophic impacts (typhoons, storms, etc.).

AN OVERVIEW OF ROOT FUNCTIONAL TRAITS OF KOREAN PINE (*PINUS KORAIENSIS*) IN NORTHEASTERN CHINA

***Jiacun GU*, Zhengquan WANG, Guoqiang GAO,Yanan WANG, Jun QIU**

Key Laboratory of Sustainable Forest Ecosystem Management-Ministry of Education, School of Forestry, Northeast Forestry University, Harbin, P.R. China

Korean pine (*Pinus koraiensis*) is an important tree species with high-values of economy and ecology. Previous studies have extensively investigated the physiology, ecology and relevant managements of this species, however, less is known in their belowground compartment, in particular fine roots (diameter ≤ 2 mm). In this synthesis, we investigated the functional root traits of morphology, physiology, chemistry, longevity and biomass allocation of Korean pine in northeastern China, and compared them with those of other tree species at the same region. The results showed that: (1) In comparison with other tree species, Korean pine has greater root diameter, longer specific root length, and lower branching ratio in the first five orders; (2) root respiration rate and nitrogen concentration of Korean pine are both lower relatively; (3) root production generally peaks in summer across two years, while mortality generally occurred in Autumn and Winter, showing the longest mean longevity (434 d) among five tree species; (4) root biomass per unit area of the first to fifth order roots were relatively lower, and only higher than that of Betula platyphylla with similar age under the same site conditions. In summary, our results suggest that Korean pine belongs to the think-root tree species with longer root life span and lower biomass, which might be of help for understanding their belowground interactions with other tree species.

EVALUATION OF SIMULATED IN VITRO RELEASE CHARACTERISTICS OF THREE PINE NUT OIL MICROCAPSULES

Yang GUO, Yihong BAO

College of Forestry, Northeast Forestry University, P.R.China

The three species of pine nut oil microcapsules which using gelatin-Arabic gum (GE-GA) and the products of Maillard reaction by gelatin-gum Arabic (GE/GA) and gelatin-gum Arabic-Maltodextrin (GE/GA/MD) as wall materials, pine nut oil microcapsules were prepared by complex coacervation. The release properties of three kinds of microcapsules were evaluated under simulated in vitro gastrointestinal fluid condition and the release curves were fitted using the kinetic models. The results indicated that all kind microcapsules exhibit slow release rate in gastric juice than in intestinal juice. Three species microcapsules' release rate of pine nut oil at 120 min was 40.55%, 22.41% and 44.87% separately. After continuous digestion at 225 min, the release rate of oil was 78.63%, 65.02% and 81.03% respectively. The MRPs-MD microcapsule exhibited more oil release in artificial gastric and enteric juice. Using the fitting of the zero-order equation, first order equation and Higuchi order equation found that three microcapsules are in line with the zero-order kinetics. The larger the particle size, the thicker the wall membrane and the smaller the release rate. The main absorption site of oil is intestine. The simulated in vitro digestion results show that pine nut oil microcapsules coated with three kinds of wall materials can achieve good release of pine nut oil in intestinal juice and are more easily absorbed by the human body.

DBH GROWTH OF 42 YEAR OLD KOREAN WHITE PINE PLANTATION BY FIRST AND SECOND THINNING

Sangyeon HAN[1], Daesung LEE[2], Jungkee CHOI[1]

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This research was conducted on the 42 year old Korean white pine plantation established in 1977 for thinning study in Kangwon National University. The first thinning was carried out with intensity of 29~69% based on number of trees when the aged was 19 years old. The second thinning was performed with the intensity of 19~67% based on the number of trees at age 37 by making heavy thinning plot thinned lightly and by making light thinning plot thinned heavily. Growth monitoring was carried out at 19, 24, 31, 37, and 42 years old, including the first and second thinning. As the result of the first thinning, DBH was higher in low density of the plot, and was the lowest in the control plot of the highest density. There was a significant difference in the growth of DBH according to thinning intensity. But there was no statistically significant difference at the 37th years so that the second thinning was carried. After the second thinning, the DBH growth was increased again. The lower density of plot, the higher the growth rate. According to the thinning intensity, DBH growth was 5.5cm ~ 8.9cm during 12years. After the second thinning, DBH growth was 1.7cm ~ 9.0cm during 5years. PAI was 0.6cm/yr ~ 1.0cm/yr immediately after the first thinning, and the growth of 0.2cm/yr ~ 0.3cm/yr before the second thinning was slowed. After the second thinning, growth was increased by 0.3cm/yr ~ 0.7cm/yr.

MODELING TREE HEIGHT, CROWN BASE HEIGHT AND EFFECTIVE CROWN HEIGHT OF PINUS KORAIENSIS PLANTATION BASED ON KNOT ANALYSIS

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Taking 1735 knots of 60 sample tress of *Pinus koraiensis* plantation in Northeast China, the dynamic growth model of tree height, effective crown height and crown base height were developed by using the screened 349 knots. Richards equation was selected as the basic model to develop a nonlinear mixed effects model of the crown base height and effective crown height and the random effect of tree level was considered. NLMIXED procedure of SAS was used to estimate model parameters. The AIC, BIC, -2LL and adjusted coefficient of determination (Ra^2), the root of mean square error (RMSE), sum of squared residuals (SSR) were used to select the optimal model and evaluate the model performance. The model was tested with independent sample data. Results indicated that the mixed effects model considering the tree effect performed better than the traditional regression model considering the goodness of fitting and validation, and the mixed model with two random effects parameters is better than just one. The time and intensity of pruning of Pinus koraiensis plantation were calculated by the developed model. According to the calculation result and the simulation chart, the difference between the height of effective crown and the height of crown base is 1.01m at the 15th year, which is more than 1m, and artificial pruning can be performed at this time. When the time is the first pruning time is the 15th year, the pruning intensity is 1.01m. A total of 5 pruning were required throughout the period of young forest, with an average pruning intensity of 1.46 m. After entering the half-mature forest, the pruning interval was not much different from that of the young forest, and the pruning intensity decreased significantly. The last pruning intensity was only 0.34m.

NEW GROWTH MODELS FOR KOREAN PINE PLANTATIONS IN NORTHEAST CHINA

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Korean pine is economically the most important tree species in northeast China. Korean pine plantations are established and managed for the production of timber and seeds. Despite the importance of the species, few models have been developed that can be used to reliably compare alternative management schedules of Korean pine plantations. Model development is affected by the fact that permanent sample plots and thinning experiments have not been designed and managed for modelling purposes. The permanent sample plots include few non-thinned plots, and weak trees are removed in thinning treatments, leading to low mortality rate. In additions, the measurement interval is irregular.

This study used optimization-based modelling approach in tree-level diameter increment and survival modelling to deal with the above problems. Models for self-thinning limit were developed to alleviate the problem of underestimated mortality arising from the features of the data. In addition, improved site index and individual-tree height models were developed. The model of Lundqvist and Korf was used as the site index model and the model proposed by Schumacher as the height model. Quantile regression was used to model the maximum stand basal area and maximum number of trees as a function of mean tree diameter and site index. Tree diameter, stand basal area, basal area in larger trees and site index were used as the predictors of diameter increment and tree survival.

The models developed in this study constitute a model set that is suitable for simulation and optimization studies. The models produced simulation results that correspond to measured stand development.

ANALYSIS OF PINE WILT DISEASE SPREAD OF KOREAN PINE IN CHUNCHEON

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This study was carried out the spread pattern and path of the infected tree in Korean pine in the area of Chuncheon City, Gangwon Province, for the control of Pine wilt disease. The Pine wilt disease in the Chuncheon city area, unlike other areas, severely damages the Korean pine, and in such areas forest operations such as thinning and clear-cutting are banned.

The survey data is based on QGIS, which is the spatial information on the trees affected by Pine wilt disease in Hongcheon-gun and the neighboring areas of Yangpyeong-gun and Gapyeong-gun in Gyeonggi-do from 2007 to 2016. Was placed in the WGS84 coordinate system. In addition, we conducted forecasting of occurrence using helicopters and U.A.V. (Unmanned Aerial Vehicles), and by vehicles and personnel to find the disease area of Pine wilt disease. In the study, the progression path of Pine wilt disease in Chuncheon City, Gangwon-do, was analyzed to flow from Gapyeong-gun, Gyeonggi-do through Gyeongchun national road, and from Gyeonggi-do, Yangpyeong-gun via the Seoul Chuncheon Expressway. In addition, it is clear that the current Pine wilt disease spreads from Chuncheon City to Hongcheon-gun in the east, and to Hwacheon in the north. Since this area is adjacent to the Demilitarized zone, Pine wilt disease control work is strongly required. In particular, the diffusion pattern and path of Pine wilt disease are analyzed not by single movement of the Monochamus saltuarius, but by vehicles, the initial incidence rate was high in the facilities used by many external vehicles such as highway service areas and golf club.

A THEORETICAL STUDY ON THE UTILIZATION OF KOREAN WHITE PINE FOREST IN ACADEMIC FORESTS

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The academic forest of Kangwon National University covers 3,146ha and has various forest type, including natural ecosystems and natural broadleaved forests and coniferous forests, including Korean White pine artificial forest. In particular, Korean White pine over 80years old account for 177ha, and the accumulation per ha constitutes a fine forest type reaching 302m^3, making it a valuable resource for forest healing environment. The use of academic forests so far has been limited to academic research, production of Korean White pine nuts, wood sap of Mono maple and wood production. Recently, however, changes in the perception of forests and the value of assets in forests as a target of utilization, not protection, have increased, and the people's desire to enjoy various forest welfare benefits through forests has been growing. Therefore, I would like to suggest a plan for using Korean White pine forest through theoretical consideration using academic forests.

First, it is constructed into various forest paths using the academic forest roads. Forest paths are divided into hiking trails, trekking trails and Dulegil, and there are no specially proposed types of forest paths. The academic forest will open a total of 40.02km of the forest roads by the end of 2019, with a slope of less than 10%. The Olle-gil in Jeju Island and Dulegil in Jiri Mountain can be constructed like a typical forest path. Through forest-walking, visitors can promote understanding of the area's history and forest and seek to promote health. It also promotes and inherits the local forest culture through storytelling, which explores the local forest culture and incorporates the humanities characteristics using Korean White pine forests.

Second, develop various forest healing programs using Korean White pine forests. The academic forest is divided into three zones: Bongmyung Management Center, Forest Environmental Education Center, and North Branch Center, and there is an 80-year-old Korean White pine forest in the area of North Branch Center, and Bongmyung Management Center has good scenic resources with artificial Korean White pine forests along forest roads. In addition, special programs of academic forests using various forest healing factors such as tree age, altitude, phytoncide, and microclimate factors are used.

Third, the forest treatment guide and Forest Trail Climbing Master trained at the Kangwon National University educational institution should be used as an expert in the program for citizens. For example, by introducing the Green Jim Program in the UK, we relieve stress through physical activities and provide a place for citizens and communities. In addition, experts develop programs in conjunction with career education programs for local youths and provide forest education for all processes such as tree planting and pruning, leading to true forest education through proper work activities.

MICROELEMENT COMPOSITION IN THE SOILS OF BROAD-LEAVED FORESTS IN SOUTHERN PRIMORYE

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The soil samples for research were collected in Mikhailovsky, Nadezhdensky, Pogranichny, Khasansky, Shkotovsky districts, Popov and Russky islands and in the Ussuriisky Reserve in the Primorye Territory. A general level of environment pollution with heavy metals can be generally described as stable. According to the research results, soil samples from the territory of the Ussuriisky Reserve and the island areas can be used as «standard» when researching the territories exposed to anthropogenic pollution because they are characterized by the lowest content of heavy metals.

COORDINATION OF INTRA AND INTER-SPECIES LEAF TRAITS ACCORDING TO LEAF PHENOLOGY AND PLANT AGE FOR THREE TEMPERATE BROADLEAF SPECIES WITH DIFFERENT SHADE TOLERANCES

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Intraspecific leaf economic spectrum (LES) traits vary considerably with leaf phenology and plant age, but whether these trait patterns significantly vary between species with different shade tolerances at local scales has rarely been examined. The presence of LES within species at local scales has recently been debated; however, the conclusions are far from universal, and whether the trait-trait relationships are modulated by leaf phenology and plant age needs to be tested. We measured six leaf traits (i.e., specific leaf area, leaf dry matter content, leaf thickness, mass-based leaf nitrogen content, leaf phosphorus content and ratio of nitrogen and phosphorus contents) among different leaf phenological stages (young, mature and old leaves) and plant ages (adult and sapling) for three temperate broadleaf species with different levels of shade tolerance. Intraspecific trait variation depended on the species and traits, and interspecies trait variation patterns were inconsistent with the LES prediction. Specific leaf area significantly decreased as the shade tolerance of a species increased, which was in contrast with the global LES prediction. Additionally, 38% and 28% of intraspecific trait variation was explained by leaf phenology and plant age, respectively, for the overall leaf traits of the three species. Generally, global LES held at the local scale, but trait-trait relationships were strongly modulated by leaf phenology and plant age. The intraspecific trait variation among the leaf phenology and plant age stages was driven by the LES axis and leaf thickness, respectively. We highlight the importance of leaf phenology and plant age on intraspecific trait variation and trait-trait relationships. We provide direct evidence of the LES at a local spatial scale and a seasonally temporal scale, but variations in LES traits are not always reliable for predicting the resource-use strategies of plants at local scales.

DISTURBANCE HISTORY RECONSTRUCTION OF NON-DISTURBED OLD-GROWTH KOREAN PINE-BROADLEAVED FOREST ON LARGE PERMANENT SAMPLE PLOT, SIKHOTE-ALIN MOUNTAIN RANGE

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Disturbance history is a sequence of events (such as the death of one or several trees) that lead to a change in stand structure, and also change the availability of resources and environmental conditions. Such events are key to forest dynamics and provide successful regeneration and coexistence of different tree species. The purpose of this study was to reconstruct the disturbance history in the old-growth Korean pine-broadleaved forest of Southern Sikhote-Alin. The results obtained are one of the steps towards understanding how forest ecosystems are formed and function without human influence. Also, these results are important for the development of methods necessary for the restoration of already disturbed forest areas. We reconstructed the disturbance history using the dendroecological approach. In total, we used 961 cores collected on an area of 5 ha from 5 dominant tree species: *Abies nephrolepis, Betula costata, Picea ajanensis, Pinus koraiensis*, and *Tilia amurensis*. Identification of periods of sharp increase in radial growth ("growth releases") was carried out using boundary-line release criteria. As a result, we reconstructed the disturbance history on the territory of 5 hectares, the length of the chronology is 255 years. Most of the time, growth releases are found in no more than 10% of trees. Additionally, 4 more severe disturbances were revealed: 1765–1774, 1845–1849, 1880–1889 and in 1960–1964. The strongest of them occurred in 1960–1964, when more than 20% of the trees showed growth release. Thus, from 1750 to 2005, no catastrophic natural disturbances were observed in the study area. Instead, rare relatively severe disturbances occurred, resulting in large canopy gaps, and more frequent minor natural disturbances when single trees died. Thus, the process of continuous and sustainable existence of the stand is caused by the dying of individual trees forming small canopy gaps. Most likely, strong winds is the reason of the formation of such gaps. Such a disturbance regime provides a steady flow of generations of different tree species and their coexistence.

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KOREAN PINE-BROADLEAVED FORESTS OF THE SOUTHERN RUSSIAN FAR EAST: FOREST MANAGEMENT AND CURRENT STATE OF RESEARCH

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Korean pine (*Pinus koraiensis* Siebold et Zucc)-broadleaved forest is one of the richest forests in Russia. They preserve the diversity of plants, and determine a specific set of animal species associated with the use of pine nuts. Korean pine–broadleaved forests are crucial for maintaining the country's biological diversity and are the main distribution area for many of the rarest species of fauna and flora. In addition, they play an extremely important social role: most of the rural population in the zone of distribution of Korean pine-broadleaved forests depends on the direct use of pine nuts or other non-timber resources (berries, mushrooms, medicinal herbs), as well as from hunting.

But now their area dramatically decreases as a result of intensive loggings. According to various estimates, with existing approaches, the remaining forest resources of the region can be exploited only 5–20 years. Therefore, in the near future there will be a question about the restoration of Korean pine–broadleaved forests. Information on the structure and dynamics of the remaining areas of virgin forests is critically important for this. And also, a study of how climate change can affect these forests in future.

In collaboration with other researchers we support a network of permanent sample plots established in different parts of the Korean pine-broadleaved forests area. Size of the most of old sample plots varies from 0.5 to 1 ha. At the present time we organize establishment of large plots (20–25 ha) which should cover species and structural diversity of the particular stand. Some key results obtained in recent years:

1. Disturbance history of Korean pine–broadleaved stands show, that in absence of fires and human impact low and moderate intensity disturbances are prevalent, stand-replacing disturbances are absent. Moderate disturbance events seem to be associated with strong winds, some peaks of growth release coincide with the time when typhoons come. The age structure tree species shows the recruitment continuity, so the stand is uneven-aged.

2. The population structure of the dominant species is characterized by similar features. The aggregated distribution pattern is typical of immature plants. Virginal plants of most species have uniform distribution. Generative plants also have uniform distribution, but some species tend to be hyperdispersed at a small spatial scale. So, distribution of generative plants is substantially homogenous, regardless of factors determined by topography.

3. We reconstructed the August–December minimum temperature for 485 years, from 1529 to 2014. As a result, we have found that one of the most important limiting factors for the study area is the minimum temperatures

of the previous autumn-winter season. We suppose that the temperature of North Pacific, expressed by Pacific Decadal Oscillation may make a major contribution to regional climate variations.

4. We used treering-based approach for determination of long-term variability in tropical cyclones (TC) activity via forest disturbance rates in northeast Asia. Our results indicate significant long-term changes in TC activity, with increased rates of disturbances in the northern latitudes over the past century. The disturbance frequency was stable over time in the southern latitudes, however. Our findings of increasing disturbance frequency in the areas formerly situated at the edge of TC activity provide evidence supporting the broad relevance of poleward migration of TCs.

Main research ongoing directions include:

a) ontogeny of tree, shrub and herbaceous species;

b) stands disturbance history and disturbance regimes;

c) natural regeneration of tree and shrub species;

d) structure of population mosaics of different tree species, spatial associations, factors influencing structure of the mosaics;

e) stand canopy structure (based on the terrestrial laser scanning).

THE SEEDS PRODUCTION AND NATURAL RENEWALOF KOREAN PINE IN «USSURIISKY» RESERVE FORESTS

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The seeds production and natural renewal of Korean pine (*Pinus koraiensis* Sieb. et Zucc.) have been studied in the 3 types of forests (sp.7, sp. 15, sp.16) in the «Ussuriyskiy» Reserve. The 36 seed traps were placed across 20 m on every sample plots (area 1 ha). The seeds crop was investigated by visual analysis using Capper's scale and seed's trap method since 2003 to 2012. The seeds were collected every 3-4 week from May to November. The seeds quality was studied by X-ray and Tetrazolium (TZ test) methods. The renewal of Korean pine was calculated on the 5 plots (10x10 m) and the obtained data counted on 1 ha.

As known, the main source for appearance the tree's seedlings is an abundant crop of the seeds. The results of investigations revealed that the crop of trees seeds is very varies. For example, the maximum crops of Korean pine cones were in 2005 and 2007.The period of the cones falling was during 1 month. The reduction of the tree seeds productivity observed after the rich harvest and then gradual increase in crops during some years.

Based on our data the complete maturation of the seeds and fruits, the preservation of the natural renewal of woody species depend on the weather conditions. It has been established that a quantity of the empty and undeveloped seeds increases during the rainless years. The mass death of the coniferous species seedlings occurred after the dry seasons in June–July. The quantity germinating seedlings on the sp.15 in 2003 decrease from 480 ps/ha to 20 ps/ha in 2008. The quantity of germinating seedlings on the sp.7 in 2003 was 60 ps/ha in 2004, than those decreased for 20 ps/ha and after abundant crop increased to 60 ps/ha in 2008.

To appearance the germinating seedling depends on viability of the seeds falling on the soil. The seeds quality varied much even in abundant crops, the best viability of Korean pine seed was 89% on the sp.7, and 98% on sp.15 and 100% on sp.16.The quantity of empty and undeveloped seeds were from 44,5 to 100% during poor harvest.

Thus, the weak renewal of coniferous species in the forests of the «Ussuriyskiy» Reserve is probably due to the following factors: the poor seed harvest; little fruit-bearing trees and low seed vitality from the old trees; bad weather conditions in the formation period of the crop (frosts in spring, long drought in the summer, high air humidity during the pollination); thick grassy cover, which prevents the seeds to fall on the ground; active eating fruits and seeds by small animals and birds; mass reproduction of the rodents which destroy the seed crop.

The analysis of dynamic of natural renewal understory of the Korean pine indicates that the forest phytocenosis on the sample plots enters into the stage of dominant foliar trees according to B.P. Kolesnikov theory.

EFFECTS OF FRUITING ON THE TRAITS OF DIFFERENT AGE NEEDLES OF *PINUS KORAIENSIS*

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Pinus koraiensis is an important edible nut tree species in Northeast China, which have an obvious masting behavior. The carbohydrates and mineral elements are important nutrient factors that affect plant fruiting. The aim of our study was to reveal the mechanism of distribution and utilization of nutrient resources from the view of the needle traits and resource allocation. To analysis the effects of fruiting on the needle traits of different needle ages of the vegetative and reproductive branches, the non-structural carbohydrates (NSC), nitrogen (N) and phosphorus (P), net photosynthetic rate (Pn), needle area and specific leaf mass (LMA) in 1-year-old needles to 3-year-old needles of the vegetative and reproductive branches were measured in the mast year. The results showed that distribution patterns of NSC, N and P in the needles of the vegetative and reproductive branches of P. koraiensis were different, which resulted in the difference of needle traits between the two branch types. Besides photosynthesis by itself, the NSC in the needles of the reproductive branches also came from adjacent non-reproductive structures. The carbohydrate consumed by fruiting could be compensated immediately, but N and P were could not compensate immediately in mast years, resulting in the decrease of Pn in the needles of the reproductive branches. LMA in the needles of the reproductive branches was significantly higher than that of the vegetative branches, indicating that more dry matter was accumulated in the needles per unit area of the reproductive branches than that of the vegetative branches.

COMPARING OPTIMAL ROTATION AGE FOR BIOMASS AND VOLUME PRODUCTION OF *PINUS KORAIENSIS* AND *PINUS DENSIFLORA* BY THINNING INTENSITY IN SOUTH KOREA

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The purpose of this study is to develop a model for rotation age for the maximum forest biomass of *Pinus koraiensis* and *Pinus densiflora*, which are the main planting species in South Korea, according to the thinning intensity. Permanent monitoring sites was installed in 45 areas for each species between 2012 and 2015, and each site consisted of control-non thinning plot(20m×20m), light thinning plot(25m×25m) and heavy thinning plot (30m×30m). The thinning ratio was 0% in the control, 20% in the light and 40% in the heavy based on the basal area, and the inventory was conducted again between 2015 and 2018. Using the data from the plots we have developed a model of DBH and height growth according to the ages for each species. Based on this, we have developed the DBH-height growth model using the growth rate of the light and the heavy. In addition, the maximum density model of Leneke was developed for each species according to the thinning intensity, using the relationship between the square mean diameter and the number of trees. Finally, volume and biomass were calculated by using stem volume equation and two variable allometric equation developed by the Korean Institute of Forest Research.

The result according to the thinning intensity showed that the average annual growth rate of volume per unit area were found to be optimal in the 39 year old for *Pinus koraiensis* and in the 31 year old for *Pinus densiflora* of the control plot, and in the 50 year old for *Pinus koraiensis* and in the 37 year old for *Pinus densiflora* of the light plot. In the heavy plot, the optimal rotation age was showed at the age of 39 years for *Pinus densiflora*, while it was not showed until at the age of 70 years for *Pinus koraiensis* in this study. Meanwhile, the optimal rotation age was showed at the age of 32 years for Pk and 46 years for Pd in the control, and at the age of 42 years for Pk and 55 years for Pd in the light. In the case of the heavy thinning, the annual average growth was continuously increased until at the age of 70 years.

RESEARCH PROGRESS AND DEVELOPMENT PROSPECT OF KOREAN PINE AND BROADLEAVED MIXED FOREST ESTABLISHED BY APPROACH OF "PLANTING CONIFERS AND RESERVING BROADLEAVED TREES"

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Zonal climax forest usually is a blueprint of local forest development. Primary forest mixed by Korean pine (*Pinus koraiensis*) and broadleaved tree species (KBMF) is the zonal climax in humid temperate areas in East Asia and certainly become the blueprint of local forest development. In 1950's when China began to do artificial regeneration on the cutting site of KBMF, they found that the planted Korean pine trees could be grown harmoniously with the pre-regenerated broadleaved trees and then an idea of "planting conifers and remaining broadleaved trees" as a regeneration strategy was initiated. By the efforts of many scientists and forest engineers, a dynamic management approach of "planting conifers and reserving broadleaved tree species" (PCRB), in which the "conifer" was mainly the Korean pine, for cutting site regeneration, over-cut forest recovery, secondary forest recovery and reestablishment to old growth attributes of KBMF has been developed and large area mixed forest by artificial planted Korean pine trees and natural regenerated broadleaved tree species (PCRB-KBMF) was established in Northeast China's temperate forest region. At the same time, large amount of researches into the establishment technology and tending and thinning biology and technology were conducted for PCRB-KBMF, and found that the regeneration of Korean pine and the growth of the regenerated population was sharply influenced by light conditions and stand density and structure of species and space should be dynamically regulated for promoting the growth of Korean pine trees and broadleaved trees harmoniously. But the established PCRB-KBMF was just occupied a little proportion of the secondary forest (including the over-cut forest and the derived forest that just composed by birch and poplar), i.e. 1 million ha PCRB-KBMF vs 14 million secondary forest, and the conducted researches were mainly in stand level and for regeneration stage, and on survival and growth indexes only, lack of studies in individual level and for succession stage, and on photosynthesis physiology and molecular indexes. Therefore, KBMF should be established on all of the sites or secondary forest land through the PCRB approach as large scales as possible, and the established PCRB-KBMF (including other KBMFs) should be scientifically managed on the basis of deep understanding of the biology and regulation regimes that the Korean pine trees responding to their adjacent broadleaved tree characteristics and the microsite conditions, i.e., the temporal and spatial patterns of growth, photosynthetic eco-physiology and photosynthesis related molecular biology of Korean pine in KBMF that represents the shade avoidance, shade tolerance and/or crowding status of Korean pine trees should be studied by establishing the microhabitat conditions with different spaces and light regimes through artificial regulating the species composition, the position and distance to Korean pine trees, the tree body features of the broadleaved trees around the Korean pine trees, and

then the competition patterns and biological mechanisms of Korean pine trees in different succession stages should be explicated and their regulation regime should be established based on such deep understandings.

NATURAL KOREAN PINE FORESTS OF THE NATIONAL PARK «UDEGE LEGEND»

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The National Park «Udege legend» is located in Krasnoarmeysky district of Primorye Territory, in the basin of the Bolshaya Ussurka river. The aim of this work is to assess the state of forests with Korean pine in the National Park «Udege Legend». Analyzing the forest management materials of the National Park «Udege Legend», we found that there are 12 forest formations in the park (fir-spruce, broadleaved- Korean pine, larch, oak, white-birch, yellow-birch, willow, chosen, poplar, ash-elm, aspen) and 2 subformations (Korean pine–spruce and Korean pine–larch). Field study was conducted in 2013–2019 at the National Park «Udege Legend». The study area includes springs Kovalevskiy, Mikhaylovskiy, Nikolayev, Pasechnyy, Trofimov, Pikhtovyy; interfluve at the confluence of the Bolshaya Ussurka and Armu rivers. Ten permanent trial plots were laid.

In the National Park «Udege Legend», Korean pine–broadleaved forests form the basis of vegetation cover and occupy 61,6% of its area, Korean pine–spruce forests – 4,7%. Currently, 5 types of Korean pine–spruce and 7 types of broadleaved–Korean pine forests at different stages of age-related and regenerative development are represented in the national park (Table).

Forest type	Quality class	Area, ha
Formation of Korean pine-broadleaved forests		**35227**
Korean pine forest with an oak and Rhododendron	V	307
Korean pine forest with an oak with Corylus and Lespedeza	V	401
Korean pine forest with a linden and an oak and Corylus	III-IV	6829
Korean pine forest with yellow birch and mixed shrubs	III-IV	19921
Korean pine forest with linden and oak with Acer and Corylus	III	4947
Valley of Korean pine forest	III	1269
Korean pine forest with Fraxinus and Sorbaria sorbifolia	III-IV	1553
Subformation of Korean pine – spruce forests		**2670**
The mossy and ferny Korean pine forest	III-IV	190
Korean pine – spruce forest with yellow birch and mossy-Corylus	III-IV	1260
Korean pine – spruce forest with linden and moss-shrub	III-IV	468
Spruce-leaved with Korean pine	III-IV	685
Korean pine – spruce forest with fir and moss-shrub	III-IV	67
Subformation of Korean pine – larch forests		**5**
Korean pine forest with larch mixed grasses	III-IV	5

These forests determine the appearance of the forest cover of the Park, they are characterized by a large set of indigenous forest generators. They occupy the middle and lower parts of mountain slopes of various expositions and steep nesses, rising to an average of 600–700 m above sea level, and also grow on drained terraces of river valleys, cones for small watercourses flooded or briefly flooded by the rivers Bolshaya Ussurka and Armu in floods.

It is a brief survey of the forests with Korean pine grown in the National Park «Udege Legend». Our future work will be aimed at studying the undisturbed Korean pine-broadleaved forests of the park.

THE EFFECT OF THINNING AND CROWN MANAGEMENT ON CONE PRODUCTION AND NUTRITIONAL COMPONENT OF PINE NUTS

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Pinus koraiensis is economically important species producing timber and nutritious pine nuts. As the demand of the pine nuts is increased as well-being food, the market has been growing and the price has risen in local markets. Pine cones are developing in the newly developing branches which are mostly located in the top of the trees. Reproductive branches are not fully hardened and prone to break easily when cones are collected. Also, tall height is the most severe hurdle to collect cones that become a major factor the price increased. Korea is one of important source of pine nut with Afganistan and China and Chuncheon is an area to produce most of pine nuts in Korea. In order to collect cones easily and safely, thinning and crown management (topping and pruning) were applied. Cone production and the quality of cones in terms of the nutritional values were examined. Cone production was increased by topping treatment compared to control and thinning forest than un-thinning ones. Difference of the tree height in topping treatment had significant effect on cone production. Trees with topped crown produced 2 times (31–40 cones per tree) more than untopped trees (18.3 cones per tree). Removal of longer shoot tops (2m long) had greater number of cones and larger seeds in width. While there was no significant differences by thinning practices in number of cones and seeds per tree (16 and 18 cones per tree and 134 and 142 seeds per cones), size of cones (fresh weight and width), and size of seeds (width of seed) are greater in thinned forest. The individual seed weight were similar in all treatment which suggest that more cones and seeds production did not affect the quality of seeds but increased the overall production. In the analysis of the nutritional value of seeds of all treatments had no significant differences. Most of seeds had high content of crude lipid (~70%) and crude protein (~17%). Moisture, ash and carbohydrates are about 4, 2 and 8 % respectively. Crown management may facilitate the cone harvesting and increase the cone production as well.

CLIMATE-GROWTH RELATIONSHIPS RECONSTRUCTIONS BASED ON THE TREE-RING MEASUREMENTS OF THE *PINUS KORAIENSIS* (KOREAN PINE) TREES, SIKHOTE-ALIN MOUNTAIN RANGE, RUSSIAN FAR-EAST

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There are very few studies of Russian Far East climate; moreover, there are no dendrochronological studies for the continental part of Russian Far East. Meanwhile, most of species present in northeastern China, the Korean peninsula and Japan grow in this region. In addition, the distribution areas of these trees often end in the south of the Russian Far East, which increases the climatic sensitivity of plants. Additionally, some parts of the forests in the Russian Far Eastern have not been subjected to human activity for the last 2000–4000 years. This makes it possible to forests extend the studied timespan. In addition, the southern territory of the Russian Far East is sensitive to global climatic changes as it is under the influence of cold air flow from northeastern Asia during the winter and summer monsoons. All of the factors listed above create favorable conditions for dendroclimatic studies.

Mixed forests with Korean pine (*Pinus koraeinsis* Siebold et Zucc.) are the main vegetation type in the study area, and they form an altitudinal belt up to 800 m above sea level. This area is the northeastern limit of the range of Korean pine-broadleaved forests, which are also found in northeastern China (the central part of the range), on the Korean peninsula, and in Japan. The Sikhote-Alin mountain range is one of the few places where significant areas of old-growth Korean pine-broadleaved forest remain. *Pinus koraiensis* – one of the most long-lived tree species in the north-east Asia forest which has undecayable woods. These allowed us to find preserved wood samples and investigated important climate-growth relationships more than 450 years. In this we present first results of our dendroclimatic research.

The territory of Russian Far East is characterized by a monsoon climate which is determined by the interaction of the Pacific Ocean and the Siberian anticyclone. So, the radial growth of Korean pine in the study region is mainly limited by the pre-growth autumn-winter season temperatures and spring – early summer precipitations. Using the tree-ring width of *P. koraiensis*, the mean minimum temperature of the previous August–December has been reconstructed for the southern part of Sikhote-Alin Mountain Range, northeastern Asia, Russia, for the past 486 years. And also we reconstructed April–June precipitation for the southern-middle of Sikhote-Alin Mountain Range for the past 300 years. These datasets are the first climate reconstructions for this region, and for the first time for northeast Asia, we present a reconstruction with a length exceeding 486 years. The results of our research are important for studying the climatic processes that have occurred in the study region and in all of northeastern Asia and for situating them within the scope of global climatic change.

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EFFECTS OF GIRDLING AND DEFOLIATION ON CONE, BRANCH AND LEAF GROWTH AND CARBOHYDRATE CONTENT IN DIFFERENT ORGANIZATION OF *PINUS KORAIENSIS*

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Taking 49-year-old *Pinus koraiensis* plantation as the research object, the girdling, defoliation (0%, 50% and 100%) and the combination of both treatments were applied on reproductive mother branches to study the effects of different treatments on the growth, biomass accumulation of reproductive mother branches, and the content of non-structural carbohydrates (NSC, consist of soluble sugar and starch) in xylem, phloem, needle and cones (seed) tissues. The results showed that the growth and biomass accumulation of current year's branches and mother branches, cones (seed) development, survival rate of current year's branches and mother branches were not significantly affected by un-girdling treatment ($P>0.05$), but all current year's branches mother branches and cones (seeds) died after girdling treatment. There was no significant effect on NSC content in seeds and seed scales ($P>0.05$). The content of soluble sugar, starch and NSC in seed scales was 3.6, 4.7 and 3.7 times higher than that in seed, and the content of NSC in female cone (seed and seed scales) was 4.8 and 2.1 times higher than that in xylem and phloem, respectively. The content of NSC in xylem, phloem and needle of three defoliation treatments for un-girdling treatment did not change significantly ($P>0.05$), but significantly higher than that of three defoliation treatments for girdling treatment ($P<0.01$), which decreased significantly with the increase of defoliation degree. Especially, the content of NSC in xylem of girdling plus100% defoliation treatment decreased by 59.0% compared with CK (soluble sugar content decreased by56.2%, starch content decreased by 56.2%), and the content of NSC in phloem of girdling plus 100% defoliation treatment decreased by 64.8% compared with CK (soluble sugar content decreased by 61.8% and starch content decreased by 77.5%). The changes of soluble sugar content in needles of two defoliation treatments for un-girdling and girdling treatment were not significant ($P>0.05$), but the starch content decreased significantly with the increase of the degree of defoliation ($P<0.05$). The soluble sugar content in needles of girdling plus 50% defoliation treatment was only 8.8% lower than CK, while the starch content was 71.3% lower than CK. The development of cones of *P. koraiensis* depleted a lot of carbohydrates, and carbohydrates produced or stored in the mother branch cannot satisfy the growth and development of cones and current year's branches. Therefore, most carbohydrates need to be imported from other tissues outside the mother branch, resulting in the consumption of carbohydrates in the whole tree.

OPTIMUM PROGRAMME AND INFLUENCING FACTORS OF EMBRYOGENIC CALLUS PROLIFERATION OF *PINUS KORAIENSIS*

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Korean pine (*Pinus koraiensis*) is an important economical tree species which produced oil, high-quality timber and nuts. Somatic embryogenesis technology of Korean pine will benefit large-scale vegetative propagation efforts and germplasm resource conservation of elite Korean pine lines. In recent studies, the embryogenic callus induction, proliferation and cryopreservation techniques of Korean pine were systematically studied by our research team. Although the mature somatic embryos and germinating seedlings of Korean pine were obtained, however, the low callus proliferation efficiency, lost embryogenic capability during the callus preservation and callus state instability existed in somatic embryogenesis of Korean pine. In this study, we studied the factors that affected the embryogenic callus proliferation of Korean pine by quadratic regression orthogonal rotation design, using embryogenic callus that induced by immature zygotic embryos at different development stages as materials. An efficient system of callus proliferation and preservation of embryogenic capability in Korean pine was established by testing the effects of different hormones concentrations, subculture period, different origin of clones and the combination of other plant growth regulators on embryogenic callus proliferation and preservation of embryogenic capability. The results showed that the embryogenic callus induction rate is limited by genotype (from different families) and collection date of explants in Korean pine. The highest induction rate of Korean pine embryogenic callus from seeds containing pro-embryo collected on July 1 was 1.67%. The DCR medium, which was supplemented with 0.25 $mg \cdot L^{-1}$ 6-BA, 1 $mg \cdot L^{-1}$ NAA, 30 $g \cdot L^{-1}$ sucrose, 500 $mg \cdot L^{-1}$ L-glutamine, 500 $mg \cdot L^{-1}$ casein hydrolysate and 6.5 $g \cdot L^{-1}$ agar, is the best medium for callus proliferation and long-term preservation of embryogenic capability in Korean pine. The different combination of plant growth regulators affected embryonic callus proliferation significantly. In the medium of combination with 2,4-D and 6-BA, embryogenesis and callus proliferation could be maintained for a long time, and the callus proliferation rate was second only to combination with 2,4-D and 6-BA. The subculture of embryogenic callus should be applied at 15 days of primary culture, in this case the callus could maintain embryogenic characteristic and proliferate greatly. Thus, in this study, an efficient system of callus proliferation and long-term preservation of embryogenic capability was established to lay a foundation for Korean pine somatic embryogenesis. The protocols will benefit large-scale vegetative propagation efforts, germplasm resource conservation of elite *Pinus koraiensis* lines, and genetic improvement based on gene manipulation and protoplast fusion.

INDIVIDUAL TREE DIAMETER GROWTH MODEL OF KOREAN PINE PLANTATION BASED ON OPTIMIZED METEOROLOGICAL FACTOR INTERPOLATION

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Korean pine (*Pinus koraiensis* Sieb. et Zucc.) is one of the three major coniferous forest species in Northeast China. By comparing different interpolation methods to simulate the meteorological factors of Korean pine growing season (from May to September), the optimal interpolation results were used to construct a diameter growth model of individual tree based on meteorological factors, which is beneficial to master the growth rules and improve the yield of Korean pine plantation. Based on 56 fixed plots data of Korean pine plantation collected in two periods of Mengjiagang Forest Farm, Jiamusi City and Liangshui National Nature Reserve, as well as Digital Elevation Model (DEM) and 32 meteorological stations data (average temperature monthly and average precipitation monthly of growing season) in Heilongjiang Province from 2014 to 2018, firstly, three interpolation methods, Ordinary Kriging (OK), Multivariable Linear Regression (MLR) and Regression Kriging (RK), are used to compare and analyze, then high precision meteorological factors data in Heilongjiang Province were obtained. Secondly, through correlation analysis method, the individual tree growth model based on meteorological factors and the basic model without meteorological factors were constructed by retaining the meteorological factors and stand factors which were highly correlated and significant with dependent variables. Furthermore, the individual tree diameter growth model with regional effect was constructed by the dummy variable method, the models were validated using an independent dataset. The predictive performance of these models was assessed by different evaluation criteria of the adjusted coefficient of determination (Ra^2) and root mean square error (RMSE). The results indicated that the individual tree growth model based on meteorological factors, Ra^2 value may increase to 0.6078 while RMSE decreased correspondingly. The individual tree diameter growth model with regional effect, Ra^2 may increase to 0.6251. The results confirmed that the interpolation accuracy of RK method for meteorological factors is significantly better than that of OK method and MLR method. The individual tree growth model based on meteorological factors can better explain the growth of Korean pine in the plot area. The individual tree diameter growth model with regional effect was the better predictor of the growth of Korean pine in the two study area.