Influence of the stand position on the slope and climate on latewood characteristics of Scots pine on dunes of South-West Estonia

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Abstract. Radial growth, latewood width and relationships between climatic variables and latewood width of Scots pines from stands of different age growing at different positions on the slopes of dunes (foot and top) were investigated in two study sites (Hdm-1 and Hdm-2) in the region of dunes in South-West Estonia. Analysis revealed no obvious regularity between tree-ring widths of pines on the top and at the foot of the dunes. Young pines showed a better radial growth at the foot. Old pines had a slightly larger average tree ring width on the top of the dunes. The average latewood width of young pines was significantly larger at the foot of the dunes. The position on the slope had no significant effect on the average latewood percentage in tree-rings. The average latewood width of the old pines was rather equal at both positions on the slope. The average latewood percentage in tree-rings was larger at the foot of the dunes. The slightly lesser latewood percentage observed in the case of the young stand was obviously related to the young age of this stand. The latewood width of young pines was not sensitive to the temperature conditions. The latewood width was positively correlated with mean monthly temperatures of December of the previous year and of June of the current season only at the foot of the slope. The high temperatures of the winter and spring months (January–June) had a positive and the warm August of the previous year a negative effect on the latewood formation in old pines in both positions. The latewood of old pines on the top of the dunes was more sensitive to the mean temperatures of the spring months and at the foot of the dunes, to the winter temperatures. Significant correlations between latewood width and precipitation were mostly observed in the case of the old pine stand. Precipitation in all months of the previous summer and autumn and in the winter months of the current year favoured latewood formation in both positions. The latewood width in the young stand was positively correlated with the precipitation in July of the current growth season but significantly only on the top of the dune.

Key words: Scots pine, radial growth, latewood, dune, climate.

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Introduction

Along with the macroclimatic conditions, which influence the growth of trees at regional scales, the understanding of the plant response to microclimatic changes becomes important when vegetation-site relationships, forest community changes, disturbances and regeneration patterns are studied within a localised site. Topography
is one of the most important factors that affect the microclimate of sites (Fritts, 1976). Many natural landforms (e.g. postglacial hills of different shape and origin, fixed dunes etc.) could be used for studies on relationships between microclimate and growth of trees. A clear zonation of the plant communities, depending on edaphic and climatic conditions, has developed on dunes around the Baltic Sea (Olsson, 1993; Wojterski, 1993). In Estonia, dunes occur mainly in the southwestern part along the shore of the Baltic Sea and on Saaremaa and Hiiumaa islands. Although the dunes in Estonia are relatively low, several plant communities (Laasimer, 1965) and forest site types (Paal, 1997; Lõhmus, 2004) can be found on them. Essential differences in tree height, site quality classes and soil properties at the foot and on the top of the dunes were reported by Örd (1972).

An earlier study (Pärn, 2003) carried out in Scots pine stands at different positions on slopes of dunes in South-West Estonia showed different radial growth rates of trees on the top and at the foot of the dunes. Moreover, the study revealed that relationships between the radial growth and mean monthly temperatures and monthly precipitation varied depending on the location of the stands on the slope.

As the monthly temperatures and precipitation during the dormant and vegetation periods vary considerably from year to year, scientists are of the opinion that it is better to study the relationships between climate and the constituents of the annual tree-ring: earlywood and latewood separately (Lebourgeois, 2000; Miina, 2000). This helps to understand the influence of the climatic variability on the annual diameter increment and on the wood properties inside of tree-rings such as early–latewood proportion, lignification of the cell walls and wood density (Gindl et al., 2000; Kilpeläinen et al., 2003). The tree-ring width and particularly the proportion of latewood within the annual ring are considered to influence the mechanical strength of the wood (Karlman et al., 2005).

The ultimate goal of this study was to provide information about responses of latewood in tree-rings to conditions prevailing at different positions on the slopes of dunes using dendrochronological methods. The specific objectives were:
1. To compare the radial growth and latewood proportion of pines at different positions on dunes.
2. To identify significant underlying relationships between climatic variables and latewood width of trees at different positions on dunes.

**Material and Methods**

**Study area and study sites**
The study was carried out in the southwestern region of Estonia. The topography of the study area is characterised by old postglacial coastal dunes. Dominant forest formations on dunes are dry boreal Scots pine (*Pinus sylvestris* L.) stands of natural origin and of varying age. The stands are growing in Luitemaa nature preserve area. No evidences of the cilmicultural activities were detected.

In the study area two study sites were chosen. The stands on these study sites are defined as *Vaccinium* site type single-species Scots pine forest stands (Lõhmus, 2004). One study site (Hdm-1) is located on the eastern slope of a high dune called Tootusemägi. The relative height of this dune is approximately 23 m. The geographical location and geomorphological characteristics of this dune are described in Mandre (2003). The stand consists of approximately 50-year-old trees without any undergrowth. The other study site (Hdm-2) is located on the eastern slope of a dune.
with relative height of 18 m approximately 1 km northeast of the study site Hdm-1. The pine stand at this site consists of trees of varying age (100–150 years), is well stocked and has no undergrowth. At the study sites trees were sampled on the top and at the foot of the dune (sample points Hdm-11, Hdm-12, Hdm-21 and Hdm-22, respectively).

**Sampling and measurements**
At sample points 12–20 dominant or co-dominant trees were sampled for analysis of radial growth. Lack of damage or defect was considered in sample tree selection. Each sample tree was cored at breast height on the northern (N) and southern (S) sides of the stem using a 4.3 mm increment corer. In laboratory each core, when dry, was mounted onto a grooved holder and the surface of the cores was cleaned and finished using sandpaper. The cores were crossdated with each other by regional pointer years to identify missing or false rings. The widths of tree rings and latewood part on cores were measured to the nearest 0.01 mm with the Metronics tree-ring measuring system. The trees with cores that were impossible to crossdate or poorly correlated with others were eliminated from further analysis.

**Climate data**
Microclimatic data for the top and the foot of the dunes were not available. Therefore, the monthly average temperatures and monthly total precipitation data were collected from two meteorological stations nearest to the selected study sites, Pärnu and Viljandi, of the Estonian Meteorological and Hydrological Institute as climatic background. The distance between sample points and meteorological stations is 26 km and 70 km, respectively. Although the records of both stations are relatively well correlated with each other over the period of the last 50 years, the averaged data were used. The regionally averaged climate data of several stations are more representative for regional climatic conditions. Tree-ring data correlate evidently more closely with the averaged climate records than with any single-station data and may therefore have more variance in common (Blasing *et al.*, 1981).

**Statistical analysis**
For each sample point the average tree-ring width, average width of latewood and average latewood percentage (latewood width to total tree-ring width ratio, %) on N and S sides of trees were computed. Average correlation coefficients of tree-ring and latewood widths between N and S sides of trees and average correlation coefficients between latewood widths and tree-ring widths were computed as well. The statistical significance of differences in the latewood characteristics of trees growing on different positions on dunes was tested by two-tail Student’s *t*-test.

In the analysis the degree of linear relationships between the tree-ring and latewood widths of pines in the different locations on the slopes of the dunes and climatic variables (mean monthly temperatures and total precipitation from the previous June to the current August) were examined using product-moment correlation coefficients. The climate data of the previous year were included in the analysis because the climate of the preceding growth season influences the tree growth in the current year (Fritts, 1976). Correlation analysis was applied for estimating the climatic factors most closely associated with tree growth. The analysis was accomplished with the STATGRAPHICS program. The climate–growth relationships were studied during the period from 1952 to 2000. The starting year of the period was
determined by the availability of the climate data.

The series of tree-ring widths contain normally a considerable amount of non-climatic signals that may include either a biological growth trend, tree disturbance signals, or both (Fritts, 1976; Cook, 1987). In tree-ring analysis, the procedure of removing non-climatic variance from tree-ring series is known as standardisation (or detrending). Standardisation transforms ring widths into new series (chronologies) of relative tree-ring indices. In the present work standardisation was accomplished with the ARSTAN (AutoRegressive STANdardisation) program version 6.04P in Dendrochronology Program Library (DPL). In detrending, the cubic 67% n spline function was used as an appropriate growth curve for dense forests, in which the competition between trees is great and individual trees face different unpredictable disturbances throughout their life (Cook & Briffa, 1990). For further analyses the ARSTAN version of chronologies that contain the strongest climatic signal possible was selected. Tree-ring and latewood index series (chronologies) were developed for all sample points at both study sites.

Along with the standardisation the mean sensitivity of the chronologies of tree-ring indices was computed. The mean sensitivity measures the relative difference in width from one ring to the next and exhibits the effect of limiting environmental factors on growth. The values of mean sensitivity range from 0 where there is no differences between adjacent ring widths to 2 where a zero value (missing tree-ring) occurs next to a nonzero one in the tree-ring width series.

Results and Discussion

Radial growth of the stands

Hdm-1. Although the trees at this site belong to the same forest stand and are of the same age, an apparent dissimilarity was detected in their radial growth. Trees growing on the top (sample point Hdm-11) had considerably smaller average diameters at breast height than those growing at the foot (sample point Hdm-12) of the dune (Table 1). The distinct growth curve of this young stand has not yet been completely formed and no clear tendencies in the radial growth of trees can be observed (Figure 1). The great competition for light among trees due to the high density and different unpredictable disturbances that individual trees face throughout their life cause complexity of the growth curves of trees and variation between trees. These reasons and different site conditions have led to the inverse growth trends and marked discrepancies in correlation coefficients between tree-ring widths at N- and S-side of trees at points Hdm-11 and Hdm-12.

Hdm-2. Although the pine stand at study site Hdm-2 consists of trees of varying age the average age of the trees at the sample points is nearly equal. The radial growth of trees at all sample points has a classical shape of the growth curve, which is best described by a negative exponential (Figure 2). During the initial stage of growth the radial growth exhibits broadest tree-rings followed by a step-by-step decrease. Against the background of the general decrease in radial growth a noticeable increase in the radial increment in 1870–1910 can be observed in the plot of ring widths for trees on the top of the dune (sample point Hdm-21). At the same sample point an increase in the radial growth of pines during the last decade may be distinguished.

Earlier analysis revealed that no obvious regularity can be observed if radial growth of pines on the top and at the foot of the dunes is compared (Pärn, 2003). Generally the young pines grow better at the lower sites. Contrary to the younger
Table 1. Summary statistics for the measured tree-ring and latewood widths.

| Statistics                                   | Sample points |
|----------------------------------------------|---------------|
|                                              | Hdm-11  | Hdm-12  | Hdm-21  | Hdm-22  |
| Average tree-ring width, mm                  |         |         |         |         |
| N-side                                       | 1.76    | 2.06    | 1.09    | 0.90    |
| S-side                                       | 1.83    | 2.23    | 1.05    | 0.87    |
| Total                                        | 1.80    | 2.14    | 1.07    | 0.89    |
| Average latewood width, mm                   |         |         |         |         |
| N-side                                       | 0.52    | 0.64    | 0.35    | 0.33    |
| S-side                                       | 0.56    | 0.70    | 0.34    | 0.32    |
| Total                                        | 0.54    | 0.67    | 0.34    | 0.32    |
| Average correlation coefficient between N- and S-side of tree-ring width | 0.783   | 0.671   | 0.830   | 0.826   |
| Average correlation coefficient between latewood and tree-ring width | 0.687   | 0.567   | 0.753   | 0.763   |
| Average latewood percentage, %               |         |         |         |         |
| N-side                                       | 31.0    | 34.1    | 32.6    | 36.1    |
| S-side                                       | 31.4    | 33.4    | 33.1    | 37.1    |
| Total                                        | 31.2    | 33.7    | 32.8    | 36.6    |
| Mean sensitivity of tree-ring series         |         |         |         |         |
| N-side                                       | 0.204   | 0.205   | 0.213   | 0.208   |
| S-side                                       | 0.195   | 0.250   | 0.207   | 0.197   |
| Total                                        | 0.199   | 0.227   | 0.210   | 0.202   |
| Mean sensitivity of latewood series          |         |         |         |         |
| N-side                                       | 0.336   | 0.324   | 0.338   | 0.346   |
| S-side                                       | 0.333   | 0.328   | 0.343   | 0.330   |
| Total                                        | 0.335   | 0.326   | 0.341   | 0.338   |
trees, the average tree-ring width of older trees generally increases from the foot to the top of the dune as was detected in the case of stand Hdm-1 in this study. Although different on the top and at the foot of a dune, the average tree-ring widths on the N and S sides of the trees in this stand were almost of the same size and correlated well with each other.

**Latewood characteristics**

**Hdm-1.** On the top of the dune (sample point Hdm-11) the average latewood width in tree-rings on the N and S sides of the trees was almost equal but was slightly larger on the S side (Table 1). Similar results were obtained in the case of the pines growing at the foot (sample point Hdm-12) of the dune. The t-test showed statistically significant ($p<0.05$) larger average latewood width of the pines growing at the foot than on the top of the dune.

Analysis revealed that the latewood width was not strongly related to the total tree-ring width. No essential differences in correlations of latewood with total tree-ring width were found when N and S sides of the trees were compared. On the top of the dune the latewood width was significantly more strongly ($p<0.05$) related to the total tree-ring width than at the foot. The moderate average correlation coefficients between the latewood widths on the N and S sides of the trees and the differences in this statistic on the top and at the foot of the dune suggest that the microclimatic conditions have an essential effect on the year-to-year variation in the latewood formation.

The average latewood percentages in tree-rings on the N and S sides of the trees were equal on both sample points. Although the average latewood percentage was slightly larger at the foot of the dune the position on the slope had no statistically significant ($p<0.05$) effect on the average relative amount of latewood in tree-rings.

**Hdm-2.** The average latewood widths were highly ($p<0.005$) equal at both sample points and on the N and S sides of the trees (Table 1). The relatively lesser aver-
The latewood width compared with the average latewood width of the young stands at study site Hdm-1 is due to the lesser average total tree-ring width of pines at this study site. The latewood width is closely related to the total tree-ring width at both sample points at this site whereas the latewood correlation with the total tree-ring width was slightly, but not significantly ($p<0.05$), higher at the foot of the dune (sample point Hdm-22).

The year-to-year variation in latewood width on the N and S sides of trees was more similar than was observed at study site Hdm-1. No essential differences in latewood width correlations between the N and S sides on the top and at the foot of the dune were detected. Therefore, contrary to study site Hdm-1, it may be assumed that the microclimate had a lesser effect on the latewood formation in this stand. However, the difference in the elevation between the top and the foot of this dune is smaller than that in the case of study site Hdm-1.

The average latewood percentages in tree-rings were almost equal on the N and S sides of the trees on both sample points. The proportion of latewood in tree rings was not much larger at the foot of the dune than on the top, in absolute values but the difference was statistically significant ($p<0.05$).

Comparison of the average latewood percentages between stands Hdm-1 and Hdm-2 revealed a slightly lesser latewood percentage in the younger stand Hdm-1. The difference was still statistically significant ($p<0.05$). According to some studies (e.g. Karlman et al., 2005) latewood percentage of pines seems to increase with increasing tree age in a way that can be approximately described by the logistic growth curve. In the case of the pine stand at site Hdm-2, the level of the average maximum values of the latewood percentage was achieved at the age of about 70 years (Figure 3). Thus the smaller values of the latewood percentage of pines at study site Hdm-1 are obviously related to the young age of this stand.

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Figure 3. Percentage of latewood from pith to bark for Scots pines on study sites Hdm-1 and Hdm-2.

Joonis 3. Sügispuidu protsent hariliku männi aastarõngastes alates säsist proovialadel Hdm-1 ja Hdm-2.
Relationships between latewood and climate
Recent studies have found that small elevation gradients have not substantially altered the tree-ring response to climate (Copenheaver et al., 2002). An earlier analysis (Pärn, 2003) on the climate-growth relationships, carried out on the same study sites used in this study, revealed no obvious regularity between the radial growth of pines on the top and at the foot of the dunes. Some variability in climate–growth relationships was observed when stands at different positions on the slope of the dunes or stands of different age were compared, however. Below relationships between latewood and climate in the same stands are considered.

**Hdm-1.** The results obtained indicate that similarly to total tree-ring widths (Pärn, 2003, Hdm-1, points 7 and 11) the latewood widths of young pines do not seem to be sensitive to the temperature conditions (Table 2). Higher correlations between latewood width and temperatures were found only at the foot of the slope (sample point Hdm-12). Analysis showed positive and statistically significant ($p<0.05$) correlations with the mean monthly temperatures of December of the previous year and of June. The correlations with the mean temperatures of the winter months (January–March) were positive and rather high but not significant.

As detected earlier, the total precipitation in certain months has a significant effect on the formation of the tree-ring width of pines at this study site. The present study showed that the latewood width was not correlated with the total precipitation in almost all months. The latewood width of pines was positively correlated with the

### Table 2. Correlation coefficients between latewood width of Scots pine (chronologies of standardised indices) with the average monthly temperatures and monthly total precipitation from previous June to August of the current year at sample points.

| Temperature | Hdm-11 | Hdm-12 | Hdm-21 | Hdm-22 | Precipitation | Hdm-11 | Hdm-12 | Hdm-21 | Hdm-22 |
|-------------|--------|--------|--------|--------|---------------|--------|--------|--------|--------|
| June        | 0.30   | 0.14   | 0.07   | 0.11   |               | -0.11  | -0.07  | 0.20   | 0.28   |
| July        | 0.27   | 0.20   | 0.09   | 0.12   |               | -0.06  | -0.25  | 0.23   | **0.39** |
| August      | -0.21  | 0.06   | **-0.52** | **-0.52** |               | 0.22   | -0.02  | 0.28   | **0.33** |
| September   | 0.04   | 0.18   | -0.15  | -0.22  |               | 0.15   | -0.09  | 0.24   | 0.17   |
| October     | 0.18   | -0.13  | 0.04   | -0.12  |               | -0.16  | -0.24  | 0.15   | 0.20   |
| November    | -0.25  | -0.17  | -0.10  | -0.02  |               | 0.06   | 0.01   | 0.14   | 0.31   |
| December    | 0.08   | 0.32   | -0.13  | -0.10  |               | -0.02  | 0.07   | 0.10   | 0.17   |
| January     | 0.08   | 0.22   | 0.28   | **0.32** |               | 0.01   | 0.11   | 0.31   | 0.31   |
| February    | 0.12   | 0.20   | 0.28   | 0.30   |               | 0.04   | 0.04   | **0.37** | 0.29   |
| March       | -0.02  | 0.24   | **0.39** | **0.54** |               | -0.15  | -0.02  | 0.28   | **0.40** |
| April       | 0.14   | 0.13   | **0.45** | **0.37** |               | -0.08  | 0.21   | -0.23  | -0.21  |
| May         | -0.11  | 0.10   | **0.38** | 0.30   |               | -0.22  | 0.04   | -0.30  | -0.31  |
| June        | 0.30   | **0.36** | 0.24   | 0.15   |               | 0.02   | -0.01  | -0.07  | -0.04  |
| July        | 0.17   | 0.09   | 0.06   | 0.05   |               | **0.32** | 0.25   | 0.23   | 0.19   |
| August      | -0.15  | -0.29  | -0.06  | 0.01   |               | -0.05  | 0.10   | -0.04  | -0.10  |

**Significant at p < 0.05**
precipitation in July of the current growth season but significantly only on the top of the dune.

Hdm-2. At this study site, positive correlations were found between both the total radial growth and latewood width and mean monthly temperatures of the winter and spring months (January–June). Among them several correlations were statistically significant ($p<0.05$). The latewood of pines on the top of the dune seemed to be more sensitive to the mean temperatures of the spring months. At the foot of the dune the winter temperatures had a greater effect. Besides this, high temperatures in the previous August limited strongly the latewood width in the next growth season at both sample points of this study site.

The results of correlation analysis emphasised the importance of precipitation in latewood formation at study site Hdm-2. The total precipitation in all months of the previous summer and autumn and in the winter months of the current year was positively correlated with the latewood widths at both positions on the slope. In some cases (Table 2) the correlations were statistically significant at $p<0.05$. The correlations were negative in spring, indicating the limiting impact of a large amount of precipitation during this period on latewood formation. Like in the case of site Hdm-1, the rainfall in July had a positive impact on the latewood width. However, the effect was not significant on neither of positions on the slope.

The detected positive impact of a warm spring on the latewood width in this study is in accordance with the results of other studies. A strong link between the latewood width and spring temperatures was described by Miina (2000) for Scots pines in eastern Finland, by Savva et al. (2003) for pines from different provenances in Russia and by Drobyshev et al. (2004) for pines in the Komi Republic. One possible reason for this is that trees in northern regions are adapted to maximally exploit the earliest available heat sum for tree-ring formation (Leikola, 1969; Hughes et al., 1999). A warm spring creates assumptions of an earlier beginning and thus of a longer growing season. It was demonstrated that the length of the growing season and temperatures during the current growing season, expressed by temperature sums, are positively correlated with the annual ring width formed (Leikola, 1969; Miina, 2000; Drobyshev, 2004). This study revealed fairly strong correlations of latewood width and total tree-ring width, especially in the case of the stand at study site Hdm-2.

The formation of latewood is connected with incorporation of lignin in cell walls and is regulated by different factors such as physiological processes in trees, availability of nutrient elements and water in soil, influence of climatic variables and stress factors etc. (Polle et al., 1997; Gindl et al., 2000; Mandre, 2002). The formation of latewood cells in pine tree-rings begins in northern conditions approximately at the end of June and last latewood cells are formed on average in the middle of August (Leikola, 1969). The positive relationships between the latewood width and precipitation in winter months and July detected also by Lebourgeois (2000) and Savva et al. (2003) suggest that an adequate moisture reserve in soil is essential for latewood formation. Increased midsummer temperatures promote intensive evapotranspiration, which suppresses photosynthetic activity of trees and therefore cells of small radial size are formed. Increased precipitation in July compensates the moisture loss, increasing tree-ring width and thus the latewood portion. In the present study, the impact of summer temperatures on the latewood width was negligible, but the effect of precipitation in July was notable, especially on the top of the dunes.
Conclusions

Radial growth, latewood width and relationships between climatic variables and latewood width of Scots pines from stands of different age growing at different positions on the slope of the two dunes were investigated.

Analysis revealed no obvious regularity exists if tree-ring widths of pines on the top and at the foot of the dunes were compared. The young pines had a better radial growth at the foot. Old pines had a slightly larger average tree ring width on the top of the dunes.

The average latewood width of young pines was significantly larger at the foot than on the top of the dunes. An essential effect of microclimatic conditions on the year-to-year variation in the latewood formation was detected. The position on the slope had no significant effect on the average proportion of latewood in tree-rings. The average latewood width of the old pines was quite equal at both positions and microclimate had a lesser effect on latewood formation in this stand. The average latewood percentage in tree-rings was larger at the foot of the dunes. The slightly lesser latewood percentage observed in the case of the young stand was obviously related to the young age of this stand.

Analysis showed that the latewood width of young pines was not sensitive to the temperature conditions. Significant correlations between the latewood width and temperatures were found only at the foot of the slope where the latewood width was positively correlated with the mean monthly temperatures of December of the previous year and of June of the current season. High temperatures of the winter and spring months (January–June) had a positive and the warm August of the previous year a negative effect on the latewood formation in old pines at both positions on the slope. The latwood of pines on the top of the dunes was more sensitive to the mean temperatures of the spring months and at the foot of the dune to the winter temperatures.

Significant correlations between the latewood width and precipitation were mostly observed in the case of the old pine stand. Large amounts of the total precipitation in all months of the previous summer and autumn and in the winter months of the current year favoured latewood formation at both positions on the slope. The latewood width in the young stand was positively correlated with the precipitation in the July of the current growth season but significantly only on the top of the dunes.

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Hariliku männi aastarõngaste sügispuidu laiuse seosed kliimateguritega ja asendiga luitenõlval Edela-Eesti luidetel

Henn Pärn

Kokkuvõte

Uurimistöö teostati kahe prooviala – Edela-Eesti kõrgeima luite, Tõotusemäe idanõlval (Hdm-1) ja sellest umbes 1 km kaugusel kirde suunas asuva luite nõlval (Hdm-2) kasvavates pohl kavukohatüübi männipuistutes. Tööteoseväärtus kasvava puistu vanus on umbes 50 aastat. Proovialal Hdm-2 kasvab 100–150 aasta vanune männipuistu. Proovipunktid juurdekavukasvuproovid võtmiseks paigutati luide harjale ja jalamil.

Puude radiaalkasv oli küll erinev luidete harjal ja jalamil, kuid selget seaduspearamust analüüsi käigus ei ilmnenud. Noorte mändide radiaalkasv oli üldiselt suurem luite jalamil, vanade mändide keskmise aastarõnga laius oli veidi suurem luite ülaosas.

Noorte mändide (Hdm-1) aastarõngaste sügispuidu keskmise laiuses oli luite jalamil oluliselt suurem kui luite harjal. Sügispuidu laiuse moodustmine korrelatsiooniku koefitsientid puude põhja- ja lõunakülgede vahel ning selle näitajate erinevus luite harjal ja jalamil annavad tõenäoline mõju esineva mikrokliima tunduvast mõjust sügispuidu formeerumisele selles puistus. Sügispuidu laiuse kõrvaline osañahtus aastarõnga kogulaiuses (sügispuidu protsent) ei olenenud oluliselt puistu asendist luite nõlval.

Vanemas puistus (Hdm-2) oli sügispuidu keskmise laius nii luite jalamil kui ka harjal, aga ka puude põhja- ja lõunaküljel enamvähem võrdne, kuid väiksem noorema puistu vastavatest näitajatest. Kuna ei esinenud sügispuidu laiuse varieeruvuse oluliselt erinevusi puude põhja- ja lõunakülje vahel ning ka nende näitajate vahelise luite jalamil ja põhja, võib antud puistu puhul eeldada mikrokliima väiksemat mõju sügispuidu formeerumisele. Sügispuidu keskmine protsent olis luite jalamil kasvavate mändide puhul suurem kui luite harjal kasvavate mändide puhul ja ületas ka noorema puistu vastavad näitajad. Sügispuidu laiuse ja aastarõnga kogulaiuse vaheline korrelatsioon oli kõrge vanema puistu puhul olenenud puistu asendist nõlval. Noorema puistu puhul oli vastav näitaja tunduvalt väiksem, eriti luite jalamil.

Noorema puistu mändide puhul ei sõltunud sügispuidu laiuse oluliselt kuu kesksest temperatuurist. Statistiliselt oluliselt korrelatsioonid leiti ainult luite jalamil kasvavate mändide sügispuidu laiuse ning juulikuun ja eelnenu aasta detsembrikuu keskmistes temperatuurides vahel. Vanema puistu puhul selgus soojemate talve- ja kevadkuude (jaanuar–mai) positiivne mõju sügispuidu moodustumisele nii luite harjal kui ka jalamil. Sealjuures soodustasid luite harjal kasvavate mändide sügispuidu moodustumist rohkem kevadkuude kõrgemad temperatuurid, luite jalamil kasvavate mändide sügispuidu laiuse oli tundlikum talvekuude temperatuuride suhtes.

Vanemas puistus küll oli sügispuidu laiuse relatiivne osa aastarõngast hulgaliselt puheem, aga võib antud puistu puhul eeldada mikrokliima väiksemat mõju sügispuidu formeerumisele. Sügispuidu keskmine protsent olis luite jalamil kasvavate mändide puhul suurem kui luite harjal kasvavate mändide puhul ja ületas ka noorema puistu vastavad näitajad. Sügispuidu laiuse ja aastarõnga kogulaiuse vaheline korrelatsioon oli kõrge vanema puistu puhul oleneneta puistu asendist nõlval. Noorema puistu puhul oli vastav näitaja tunduvalt väiksem, eriti luite jalamil.

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