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FOREST GAPS EFFECT ON GROUND VEGETATION AND FOREST REGENERATION IN THE VIŠTYTGIRIS BOTANICAL-ZOOLOGICAL RESERVE

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Aiming to assess the effect of microclimate on vegetation in forest gaps and to determine the changes of woody and ground vegetation in the gaps of different size the study was carried out in Vištytgiris botanical-zoological reserve in 2013.

After the assessment of the woody vegetation, projection coverage of ground vegetation, soil temperature, moisture and soil pH, also solar radiation, the peculiarities of woody vegetation in forest gaps of different size were evaluated and the causing microclimatic factors were distinguished. Six naturally regenerated species were determined in small forest gaps, seven species - in medium-sized forest gaps and five species – in large forest gaps. Low-light demanding tree species were dominated in small gaps, low-light demanding species and requiring more light were mostly frequent in the medium-sized gaps, and more light and higher temperature demanding species were dominated in large gaps. The highest amounts of herbaceous species were found in the large forest gaps. The highest total radiation was recorded in large plots. The highest soil temperature and the lowest moisture content were found in small gaps, and the lowest soil temperature and the highest soil moisture content was - in the medium-sized gaps. The obtained findings showed that the most optimal conditions for self-regeneration of the forest were in the medium-sized forest gaps in Vištytgiris botanical-zoological reserve.

Key words: species composition, forest gaps, natural regeneration.

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INTRODUCTION

Forests, being the main Lithuanian natural resources and a guarantee of ecological stability, are an important habitat for wildlife and vegetation, protect soil against erosion, regulate regime and prevent the quality of ground and surface waters, absorb carbon dioxide and accumulate carbon in biomass (Juodvalkis & Kairiūkštis 2009, Venckus 2010).

Most of the Lithuanian forests are self-regenerated and heterogeneous. Compared to the Central and Southern Europe, the forest biodiversity is abundant in Lithuania. In the forests, the areas not covered with forest, also areas surrounded by a natural or semi-natural landscape elements (meadows, marshes, fields, etc.) with rich variety of components still exist (Kurlavičius 2006, Šepetienė 2008).

Forest ecosystem is constantly subjected to different negative effects of biotic and abiotic agents. Furthermore, this leads to the specifics of forest vegetation species composition, structure and peculiarities of its development processes. Forest or canopy gaps in the forest cover appear as a response of natural or artificial disturbances when trees when trees are damaged or die (Yamamoto 2000, Sapkota & Oden 2009). For instance, one of the leading causing factors is wind (Peterson & Pickett 1990). Small forest gaps usually appear as a result of die or wind fall, trunk broken or uprooted individual trees.

Regeneration processes in forest gaps depend on several environmental factors, also physiology and behavior of regenerating species (Lawes et al. 2007). Regeneration also depends on physical gap characteristics. Several studies have revealed that gap size is one of the most important characteristics affecting the regeneration of various tree species (Brokaw 1985, Li et al. 2005). In the forest gaps of different size, different lighting and shape (Dahir & Lorimer 1996), variety of the soil moisture or nutrient concentrations regimes, which determined as gap characteristics (Van Der Meer & Bongers 1996), could be obtained. Bullock (2000) found that the competition for light, nutrients and water is weaker in large gaps compared to small gaps. Usually larger forest gaps are occupied with species which require more light and higher temperatures. Such forest gaps are surrounded by trees which grow further from each other and thus more light enters the area. The higher light regime causes the higher vegetation diversity and more pronounced differentiation of trees (Poulson & Platt 1989, Messier et al. 1999). In contrast, in small forest gaps the low light levels are found, and the plants almost constantly grow in the adjacent tree shade, they are overshadowed and compete for light (Sapkota et al. 2009; Hammond & Niklas 2011). The seedlings of trees and other plant species regenerated in the small forest gaps are more adapted to the unfavorable environmental conditions (White & Pickett 1985, McCarthy 2001, Sturtevant et al. 2004).

The variety of other affecting factors are subjected in literature, for example, the height, diameter and stand structure of the surrounding trees, gap age, the number, causes and sizes of tree fall (Denslow 1980, Uhl et al. 1988, Yamamoto 2000, Schnitzer & Carson 2001, Gagnon et al. 2004). Some biotic factors including the characteristics of gap-creating species (Boettcher & Kalisz 1990) or the surviving of understory species in the gaps (Taylor & Qin 1988) are not less relevant.

Due to unfavourable conditions, size of the forest gap and soil fertility, many trees, shrubs and ground vegetation species disappear or grow poorly (Gray & Spies 1996, Meyer 2008). Climate changes could also cause the different formation of forest gaps and even could disturb the forest vegetation in the gaps (Gray & Spies, 1997). The intensity of natural forest thinning and trees differentiation depends on the tree species and environmental conditions. In more fertile soils, the number of trees decreases faster with increasing stand age compared to the soils of low fertility (Ozolinčius 2008). When trees start to compete for moisture and nutrients with adjacent weeds, the competition for light becomes the most important (Malinauskas 2011).

When assessing the success and condition of the regenerated seedlings, the main favourable and unfavourable factors should be identified. Naturally, seeds for new trees generation come from adjacent stands. Self-regeneration of forest stands depends on the tree species, seed structure, year, the distance from the seed source, ground vegetation layer, forest floor thickness, also abiotic factors, including light, temperature, air and soil moisture (Kozlowski 2000, Baskin & Baskin 2001, Suchockas 2004, Tweddle et al. 2003, Juodvalkis & Kairiūkštis 2009, Nathan et al. 2011). Natural forest regeneration has a number of advantages: new generation of forest stand well corresponds with the forest site type, climate, and soil properties (Šeben et al. 2013). Forest regeneration depends on many conditions. For example, the new generation of trees and undergrowth is affected by the viability of forest ground vegetation cover, species composition and projection cover (Bačkaitis & Riepšas 2003; Gaudio et al. 2011). Young tree seedlings compete for water and soil nutrients with ground vegetation, and this inhibits tree seeds germination and seedlings growth (Paris et al. 1995, 1998, Frochot et al. 2002, Gama et al. 2006, Michalet 2007). Tree regeneration is also influenced by the species composition, diversity and age of the surrounding stand. Each tree species require for specific soil moisture, forest litter thickness and soil physical properties (Gradeckas & Malinauskas 2011, Liira et al. 2011). The content of soil organic matter causes soil fertility, and, moreover, it has an impact on the seedlings viability (Marcinkonis ir kt. 2011). Soil moisture is also an acting factor for seed germination and seedling development. The more favorable conditions for seed germination are found under the stand cover where temperature and moisture are less variable (Karazija 2008). Aim of this study was to evaluate the effect of microclimate on vegetation in forest gaps and to determine the changes of woody and ground vegetation in the gaps of different size.

MATERIAL AND METHODS

Site characteristics. The study was conducted in the Vištytgiris botanical and zoological reserve which is located in the territory of Vištytgiris forest of State Vištytis regional park (Fig. 1).

The Vištytgiris botanical and zoological reserve was established in 1992 aiming to preserve the typical broad-leaved forest communities with mixed and rich flora and fauna. The reserve covers an area of 657 ha, which represents 6.7% of the total area of the park. The reserve covers the central part of the forest Vištytgiris (Report of Vištytis Regional Park 2011).

In this territory, mean annual precipitation is 550-650 mm, mean annual air temperature is 7ºC and mean wind speed is 3-3.5 m/s (Lithuanian climate... 2013). Soils are *Luvisols* and *Albeluvisols* (Volungevičius & Kavaliauskas 2012). Forests in the Vištytgiris botanical and zoological reserve are assigned as forests for protection of ecosystems or second forest group forests of special-purpose according the distribution of forest land area by forest groups and subgroups in Lithuania. Only regeneration fellings, including all types of intermediate clearings and salvage cuttings, are allowed in the naturally mature stands of the second group forests (Forest felling rules 2011).

The botanical studies showed that there are 439 species of spontaneous flora vascular plants, including 17 species of vascular spore forming plants, 2 species of gymnosperm and 420 species of angiosperms in the area of Vištytgiris botanical-zoological reserve. Also, 21 tree species, 111 moss species and 418 species of herbaceous plants were registered. Twelve species of plants and 8 species of mosses are included in the Red Book of Lithuania, for example, *Hordelymus europaeus* (L.), *Hedera helix* L., *Dactylorhiza baltica*, *Arctium nemorosum* Lej. and others.

In the reserve, forest stands are of natural origin, the dominant tree species are *Quercus robur* L., *Picea abies* L., *Carpinus betulus* L., *Populus tremula* L., *Betula pendula* Roth, *Tilia cordata* Mill., *Acer platanoides* L., *Fraxinus excelsior* and *Pinus sylvestris* L. *Alnus glutinosa* (L.) Gaertn. and *Salix caprea* are found in more humid places. In the undergrowth layer grow Norway spruce with admixture of birch sp. and aspen, in the underbrush layer grow hazel, rowan and honeysuckle. The ground vegetation is characterized by high species diversity; the species like *Rubus idaeus* L., *Trientalis europaea* L., *Vaccinium myrtillus* L., *Aegopodium podagraria* L., *Anemone nemorosa* L. are found (Report of Vištytis Regional Park 2011).

Data collection. For the assessment of woody and herbaceous vegetation, accounting areas of three different sizes were randomly selected in

2013, June. Totally, five small areas of 20 m^2, twelve medium-sized areas of about 50 m^2 and five large areas of about 150 m^2 were chosen. In each selected area, the woody vegetation and projection coverage of herbaceous vegetation were assessed. Only the seedlings of target species growing in the fertile sites of normal moisture (Nc forest type) were calculated. The lighting in the open area and under the canopy layer, soil temperature, moisture and pH were measured.

For the assessment of woody vegetation, transects of 2 meters width along the accounting area north-south direction were distinguished (Lithuanian National ..., 2003). The density of seedlings necessary to regenerate the stand is indicated in the Rules for reforestation and afforestation. The amount of the seedlings in mixed forest stands was assessed in the accounting areas according to the amount of each species up to 50 cm and above 50 cm. The recommended norm of the seedlings was calculated for individual species. Further, the values for woody vegetation were re-calculated as number of seedlings per hectare (units / ha).

The projection coverage of ground vegetation (in percent) was assessed visually according the forest vegetation methodology applied in the forest monitoring (Tallent-Hansel, 1994). For

Fig. 1. Research plots in Vištytgiris botanical-zoological reserve.

the assessment of ground vegetation projection coverage, three squares of 1 m^2 were randomly selected in each plot (Ozolinčius, 2008).

Soil moisture and temperature was measured using a portable device WET, the soil pH using a portable device PNT 3000. These indicators were measured in the soil at a depth of 5 cm in the center of the accounting area, at the edge and in the forest, 5 meters from the accounting area. The lighting or luminous flux, which penetrates through coniferous or deciduous tree canopy and falling down to the lower vegetation layers, was measured using the device HemiView Canopy System. The hemispherical images were made in the central part and at the edge of the small, medium-sized and large areas and next to edge - in the forest. For the analyses of the hemispherical images, a computer program HemiView was used. The following lighting indices were assessed: direct, diffused and total radiation.

Data analyses. The descriptive statistical data analysis and correlation analysis were used. All statistical analyses were carried out using the STATISTICA 8.0 software.

RESULTS AND DISCUSSION

Regeneration patterns of woody vegetation in forest gaps. Small forest gaps were dominated by undemanding to the lack of light tree species (Fig. 2). In the gaps of this size, Norway spruce and Common oak were dominated, and comprised four parts in the species composition.

In the medium-sized gaps, both tolerant to poor lighting and demanding more light species were usually found. On average, the Norway spruce dominated among other tree species in the medium-sized forest gaps, and it comprised five parts in the species composition, while small-leaved lime (*Tilia cordata*) comprised only two parts (Fig. 2). Meanwhile, oak trees comprised only one part in tree species composition. In the large gaps, forest tree species that require intense lighting and higher temperature were normally found. Our data showed that aspen was dominated and comprised five parts in the species composition.

According to H. Ellenberg (1991), Common oak, aspen, Silver birch seedlings were attributed to semi-light-demanding species, while Norway spruce and small-leaved lime to – semi-shade-prefering species.

Projection coverage of herbaceous plants in forest gaps. Based on our data, projection coverage of herbaceous vegetation in the small gaps was low (Fig. 3). According to the vegetation aggressiveness groups obtained by Karazija (2008), herbaceous cover in the small gaps was assigned to the first group of aggressiveness. Totally, in small gaps 17 herbaceous plant species were found. The highest average projection coverage was by *Melica*

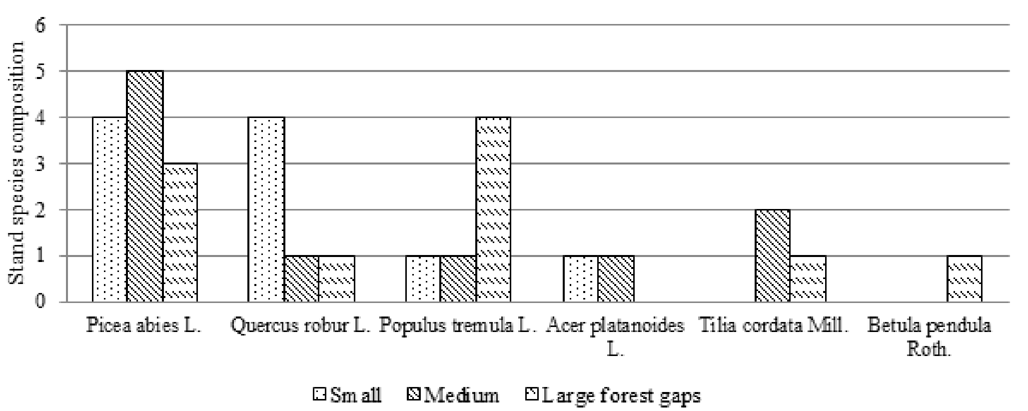

Fig. 2. Dominated tree species in small, medium-size and large forest gaps.

nutans L. (21%), *Lamiastrum galeobdolon* L. (15%) and *Calamagrostis arundinacea* L. (10%) (Fig. 3). The lowest average projection coverage was by *Aegopodium podagraria* L., *Dryopteris filix-mas* L. Schott, *Equisetum sylvaticum* L. and *Rubus idaeus* L.

Projection coverage of herbaceous vegetation in the medium-sized gaps varied in a very wide range from 1 to 80%. According to the impact on forest regeneration, grass cover of the medium-sized gaps was placed in the second group of aggressiveness. The highest average projection coverage was by *Impatiens parviflora* Dc. (35%), *Lamiastrum galeobdolon* L. (15%), *Oxalis acetosella* L. (13%) and *Vaccinium myrtillus* L. (11%). Minimum of 1% average projection coverage was found for *Hepatica nobilis* Mill., *Murorum Hieracium* L., *Paris quadrifolia* L., *Urtica dioica* L. and 2% - *Rubus nessensis*.

On average, projection coverage of herbaceous vegetation in the large gaps varied from 2 to 48%. According to the influence on forest regeneration, grass cover of large gaps was assigned to the third group of aggressiveness, with the exception of only one assessed gap. The vegetation cover of the mentioned gap, due to its exceptionally high and undergrowth-shading dense grass, was assigned to the fourth group of aggressiveness. The highest average projection of 48% was found for *Calamagrostis arundinacea* L., 40% for *Urtica dioica* L., *Melica nutans* L., and 24% - for *Aegopodium podagraria* L. The lowest coverage of 2% was determined for *Carex nigra* (L.) Reichard.

Forest regeneration is undoubtedly influenced by herbaceous forest vegetation. Herbaceous plants compete with regenerating plants for lighting and soil nutrients. This influences the vitality of regenerating plants, slows their growth, and may increase the mortality of naturally regenerated seedlings. It was found that naturally regenerated seedlings often die as a result of competition with plants, water and nutrient deficiency or suppression even on fertile sites during arid years (Nilsson Orlander 1999, Nilsson et al. 2006). Based on the results of this study, we could conclude that forest gaps of all three sizes were mainly dominated by grass cover of medium aggressiveness. In this particular case, we could assume that the obtained grass cover would not cause much damage to forest regeneration in the assessed forest gaps. However, due to the specific microclimatic conditions or heterogeneity in the individual forest sites, very dense herbaceous vegetation cover can be formed.

Soil temperature in the forest gaps. Determining the change of woody and herbaceous vegetation in the forest gaps, it is important to evaluate site microclimatic conditions (soil temperature, moisture and pH) and the dependence of

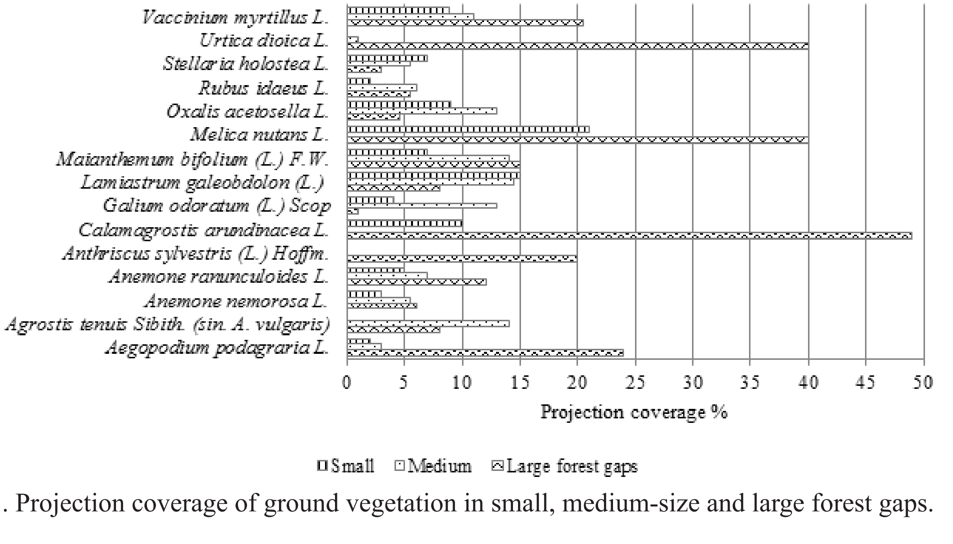

Fig. 3. Projection coverage of ground vegetation in small, medium-size and large forest gaps.

Table 1. Soil temperature in small, medium-size and large forest gaps

	Soil temperature, °C			Standard deviation	Variation coefficient, %
	Mean ± standard error	Minimal	Maximal		
Centre of small gap	25.94 ± 0.80	23.70	28.00	1.79	6.89
Centre of medium-sized gap	21.55 ± 0.44	18.60	23.70	1.51	7.10
Centre of large gap	24.78 ± 0.73	22.70	27.00	1.64	6.63
Edge of small gap	23.78 ± 0.88	21.30	26.20	1.97	8.28
Edge of medium-sized gap	19.95 ± 0.31	17.60	21.50	1.08	5.47
Edge of large gap	22.62 ± 0.59	21.10	24.50	1.33	5.86
Forest	21.06 ± 0.65	19.10	23.20	1.54	7.16

vegetation on changing environmental conditions. According to our data, the highest soil temperature was found in the small, while the lowest – in the medium-sized gaps (Table 1).

The largest difference ranging from 4.9 to 5.1 degrees between the minimum and maximum soil temperature was found in the centre of medium-sized gaps, on the edge of small gaps, and in the forest near small and large gaps. Minimum of 2-3 degrees difference was found at the edge of large and in the forest near medium-sized gaps.

Statistically significant correlation ($r = -0.94$, $p = 0.05$) between soil temperature and Norway spruce (*Picea abies* L.) natural regeneration was found in the large gaps, i.e. the amount of naturally regenerated seedlings decreased at higher temperatures. In the case of aspen (*Populus tremula* L.), with increasing temperature, a higher amount of naturally regenerated seedlings ($r = 0.99$, $p = 0.01$) was found. In the medium-sized gaps a decrease in the number of naturally regenerated seedlings of common maple (*Acer platanoides* L.) ($r = -0.91$, $p = 0.03$) was recorded at higher temperatures.

Soil moisture content in the forest gaps. Along with the assessment of the vegetation cover, measurements of soil moisture content were conducted in the gaps of all sizes. Summarising the results of these measurements, we concluded that the maximum soil moisture content was found in the center, near the edge, and in nearby growing forest of medium-sized gap, while the lowest - in the small gaps (Table 2).

The largest difference between the maximum and minimum soil moisture content was found in the medium-sized gaps, the lowest - in the small gaps.

Statistically significant correlation ($r = -0.99$, $p = 0.01$) between soil moisture content and Norway spruce (*Picea abies* L.) natural regeneration was recorded in the small gaps, i.e. under higher humidity, the amount of naturally regenerated spruce seedlings decreased. In the medium-sized gaps a higher number of spruce (*Picea abies* L.) seedlings ($r = 0.63$, $p = 0.04$) was found with increasing humidity. In the case of Silver birch (*Betula pendula* Roth), with increasing humidity, the number of natural seedlings increased ($r = 0.99$, $p = 0.01$) in the large gaps.

Soil pH in the forest gaps of different size. The seeds of individual tree species germinate best at a given pH of the soil. The predominant species of naturally regenerated seedlings was Norway spruce, which grows best when the pH is about 5.0 (Karazija, 2008). In summary, soil pH data showed that the highest soil pH difference between the minimum and maximum values was in the center of medium-sized gaps (pH differed by 1.57 pH units), on the outskirts of the large gaps (by 1.46 pH units), and the smallest difference was in the center of large and at the edge of small gaps (Table 3).

Table 2. Soil moisture in small, medium-size and large forest gaps

	Soil moisture, %			Standard deviation	Variation coefficient, %
	Mean ± standard error	Minimal	Maximal		
Centre of small gap	4.26 ± 0.90	1.40	6.20	2.01	47.40
Centre of medium-sized gap	9.97 ± 2.07	2.10	26.80	7.18	71.99
Centre of large gap	4.88 ± 1.80	1.40	11.40	4.02	82.44
Edge of small gap	8.00 ± 1.29	4.70	11.20	2.88	36.00
Edge of medium-sized gap	13.42 ± 2.84	4.70	39.60	9.85	73.37
Edge of large gap	11.08 ± 2.47	4.30	17.50	5.52	49.85
Forest near small gap	10.94 ± 2.12	6.70	17.40	4.73	43.28
Forest near medium-sized gap	18.70 ± 3.15	7.80	45.70	10.90	58.34
Forest near large gap	22.18 ± 4.85	5.70	31.60	10.85	48.93

Table 3. Soil pH in the forest gaps of different size

	Soil pH			Standard deviation	Variation coefficient, %
	Mean ± Standard error	Minimal	Maximal		
Centre of small gap	5.29 ± 0.20	4.68	5.82	0.45	8.46
Centre of medium-sized gap	4.88 ± 0.12	4.31	5.88	0.42	8.56
Centre of large gap	5.77 ± 0.19	5.20	6.24	0.43	7.44
Edge of small gap	5.17 ± 0.22	4.71	5.81	0.50	9.60
Edge of medium-sized gap	4.61 ± 0.11	4.04	5.39	0.38	8.27
Edge of large gap	5.43 ± 0.24	4.73	6.19	0.54	9.87
Forest	4.63 ± 0.14	4.30	5.20	0.34	7.41

A statistically significant relationship was found in the small gaps between soil pH and the amount of naturally regenerated seedlings of Norway spruce (*Picea abies* L.) ($r = -0.96$, $p = 0.04$), common oak (*Quercus robur* L.) ($r = 0.96$, $p = 0.01$), i.e. when pH was 5.23±0.06, the number of Norway spruce seedlings decreased, while in the case of oaks – it increased. In the medium-sized gaps the number of Norway spruce (*Picea abies* L.) ($r = 0.81$, $p = 0.01$) seedlings increased at pH 4.75±0.14. In the large gaps, the number of Silver birch (*Betula pendula* Roth.) ($r = -0.98$, $p = 0.05$) seedlings decreased at pH 5.60±0.17.

Lighting in the forest gaps and under the tree canopies. Lighting, as well as other environmental factors, affects plants regenerating under the canopy of stands. It was found that the amount of undergrowth increases with the increase of light. Under enhanced lighting, natural regeneration or offsprings flourish. Assessing the success of regeneration in fertile forest sites, the flourishing of the underbrush and grassy vegetation is taken into account. Depending on various conditions and tree species, the cover under tree canopies receives about 30% of the total radiation (Juodvalkis et al., 2010). Our data showed that mean total radiation that

Table 4. Solar radiation in the forest gaps of different size. Values are given as the Mean ± Standard error

	Dispersed radiation	Direct radiation	Total radiation
Centre of small gap	231 ± 15.4	1182 ± 201.5	1413 ± 211.7
Centre of medium-sized gap	197 ± 6.9	499 ± 46.0	696 ± 50.0
Centre of large gap	320 ± 24.0	708 ± 61.0	1027 ± 59.0
Edge of small gap	196 ± 17.1	589 ± 28.4	785 ± 14.6
Edge of medium-sized gap	177 ± 7.9	513 ± 39.0	690 ± 40.0
Edge of large gap	242 ± 19.1	511 ± 34.8	754 ± 16.2
Forest	204.7± 7.1	677.3 ± 37.7	882.0 ± 43.3

falls within the center of a small gap comprised 17.60%, that of medium-sized gap - 29.58%, that of a large gap - 31.16% (Table 4).

In the medium-sized gaps a statistically significant relationship was recorded between Norway spruce (*Picea abies* L.) and diffuse ($r = 0.70$, $p = 0.02$), direct ($r = 0.63$, $p = 0.04$), and total ($r = 0.67$, $p = 0.02$) radiation, small-leaved lime (*Tilia cordata* Mill.) and diffuse radiation ($r = -0.79$, $p = 0.01$), i.e. under more intense lighting the number of natural Norway spruce seedlings increased, while that of lime – decreased.

CONCLUSIONS

Species composition and quantity of woody vegetation in a forest site depended on its size. Small gaps were dominated by a lack of light-tolerant, medium-sized – by the lack of light-tolerant and requiring more light, while large gaps – by more light and higher temperatures requiring species.

Species composition of vegetation abounds depending on the size of the gaps. In the small gaps 17 species of herbaceous plants were found, in the medium size - 28 species, and in the large gaps - 30 herbaceous plant species. In the medium-sized gaps the overall projection coverage was the highest (80%), and the lowest (50%) - in the small gaps.

The part of the total radiation which falls to the center depended on the size of gaps: maximum radiation of 31.16% was found in the large gaps, and the minimum of 17.60% was found in the small gaps.

The highest soil temperature and the lowest humidity were ascertained in the small gaps, the lowest soil temperature and the largest soil moisture - in the medium-sized gaps. Soil temperature and moisture content had a statistically significant impact on the amount of Norway spruce (*Picea abies* L.), common maple (*Acer platanoides* L.), aspen (*Populus tremula* L.) seedlings.

The soil of small and large gaps was slightly acidic (pH 5.17 to 5.77), while that of medium-sized - averagely acidic (pH 4.61 to 4.88). Statistically significant relationship was found between soil pH and the number of Norway spruce (*Picea abies* L.), common oak (*Quercus robur* L.), silver birch (*Betula pendula* Roth.) seedlings.

The optimum conditions for natural forest regeneration are in medium-sized gaps. In gaps of this size the best microclimatic conditions for various tree species are formed.

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