QUALITY ASSESSMENT OF EUROPEAN ASH *FRAXINUS EXCELSIOR* L. GENETIC RESOURCE FORESTS IN LATVIA

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Abstract
In Latvia, two European ash (*Fraxinus excelsior*) genetic resource forests (GRF) have been designated in Skrīveri and Bērvircava. However, as the degree of damage of ash by the pathogenic fungus *Hymenoscyphus fraxineus* has increased, many stands have died and many do not comply anymore with minimum requirements for GRF. The aim of the present research was to evaluate and examine the quality of ash GRFs. In each forest unit, one 20×20 m plot was established, and the first (E3) and second (E2) layer projective cover of each species was determined in August 2014. All undergrowth and advance regeneration species were counted and the degree of ash damage by *H. fraxineus* was determined along a diagonal 25×1 m transect in each plot. In total, 101 plots were established. Quality evaluation was carried out according to the basic criteria for selection of GRF as well as based on criteria cited in other research. Their variation was established by using principal component analysis. Ash in layer E3 was better maintained in Skrīveri, but ash regeneration there was worse, as well as a higher degree of damage by *H. fraxineus* was observed. Ash regeneration density is significantly influenced by its cover on layers E3 and E2 as well as by tree species dominating the growth. The most valuable GRFs have been maintained in Skrīveri where 50% of units were rated of average quality and few of bad quality. In Bērvircava, 56% of forest units were of bad and very bad quality.
Key words: Descriptors, natural regeneration, ash dieback, European Forest Genetic Resource Program.

Introduction

The objective of genetic resource forests (GRF) is to maintain the genetic diversity and gene pool of a concrete tree species; and additionally they also have potential economic, environmental, scientific and social value (The State of…, 2014). These forests can provide for adaptation and evolutionary processes of the forest and trees growing in it; they also foster stand productivity (The State of…, 2014).

Within the framework of the European Forest Genetic Resource Program (EUFORGEN), 59 European ash (*Fraxinus excelsior*) gene reserve forests and protected forest areas have been designated in Europe, two of them are situated in Latvia (Pliûra and Heuertz, 2003). The EUFORGEN database indicates that the forest areas are managed for wood production and/ or multiple uses or services (Pliûra and Heuertz, 2003), but several genetic resource forest units are also specified as woodland key habitats, therefore economic activity in these forest units is restricted. In Bērvircava, selective cutting is allowed in three forest units for research purposes.

Ash GRFs are threatened by the ever-increasing infection rate with the pathogenic fungus *Hymenoscyphus fraxineus* which leads to ash dieback. In the last 20 years, the disease has spread widely throughout Europe and it has been found in more than 20 countries. The Baltic states were among the first where ash stand destruction was identified at the beginning of the 1990s (Stener, 2013), but the disease was confirmed in Latvia in 2007 (Kenigsvalde et al., 2010).

Prior to ash dieback, European ash was the most common hard-wood tree species in Latvia and one of the few tree species that regenerated well naturally (Laiviņš and Mangale, 2004). Natural regeneration is one of the basic GRF requirements (Koskela et al., 2013). At present, European ash comprises only 14 582 ha (0.5%) of the total forest area. The increasing degree of ash damage can lead to serious ecological consequences to European biodiversity and forest ecosystems (Pautasso et al., 2013). In Britain, 953 species are connected with ash stands, and the existence of 44 species fully depends on ash (Mitchella et al., 2014). Notwithstanding the extended history of the disease, further development of ash stands cannot be foreseen, because it greatly depends on persistence of natural resistance and further host organism and pathogen interaction over a longer period of cohabitation (McKinney et al., 2011). Therefore genetic resource forests (GRF) stands have become scientifically important forest stands and they are genetic reserves of European ash.

Pan-European minimum requirements for dynamic gene conservation units stipulate that each GRF stand must have a management plan which, based on systemic surveys, is updated every 5 or 10 years (Koskela et al., 2013). In the present study all ash GRF units were surveyed. As ash dieback increases, it becomes evident that ash GRF minimum requirements stipulating that the minimum size of a genetically viable population is 50, preferably 500 to 1000 trees and 400 reproducing trees per hectare (Koskela et al., 2013), cannot be fulfilled in many forest units. At present, EUFORGEN have not established requirements for re-evaluation of the existing stands, so the study is based on the aforementioned requirements for new GFR stand selection. In Latvia, the features of genetic

Table 1

Ash GRF criteria for division into quality classes

Ash quality and descriptor class	Primary descriptors			Secondary descriptors				
	Ash projective cover, %		Ash regeneration, specimens per hectare [1]	Second and undergrowth layer cover, % [2]	Spruce projective cover E3, E2, %	Degree of *H. fraxineus* damage, %	Broad leaved projective cover E3, %	Competition of other species, number [3]
	E3	E2						
1.	> 17	> 11	> 6001	0 – 30	0 – 0.5	0 – 10	6	0 - 15
2.	13 - 16	4 – 10	3001 - 6000	31 – 50	1 – 3	11 – 25	4 - 5	16 - 35
3.	8 – 12	1 - 3	1001 - 3000	51 – 70	4 – 8	26 – 60	3	36 - 60
4.	4 – 7	0.5	801 - 1000	71 – 80	9 – 15	61 – 99	1 - 2	61-100
5.	0 - 3	0	0 – 800	> 81	> 16	100	0	> 101

[1] The number of ashes counted in transect has been recalculated to hectares.
[2] Total projective E2 cover.
[3] Other regeneration growths and undergrowths counted in transect.

forests, namely descriptors, have been developed within the framework of the research 'The long-term maintenance and sustainable use of Latvian forest tree genetic resources' (Gailis et al., 2008), but the descriptors have not been adopted and are not used in practice.

The objective of the research was to survey both GRF ash stands in Latvia, determine their present state and to give a quality evaluation according to a framework of five classes. As ash cover has decreased dramatically, one of the tasks set by the research was to determine the factors that influence the generation of new ash advance regeneration. Whereas Latvian descriptors have been established for Norway spruce (*Picea abies*) genetic resource forests, one of the objectives of the research was to identify and analyse the features that best characterize European ash forests.

Materials and Methods

The research was carried out in August 2014 in two ash genetic resource forests, which are situated in the central part of Latvia: Skrīveri region (Skrīveri, geographical location: X 564257, Y 6281096) and Jelgava region (Bērvircava, geographical location: X 486817 , Y 6251196). Skrīveri forest area is 155.2 ha, on which 28 GRF units were surveyed. In Bērvircava forest 73 units covering 239.6 ha were surveyed. In both regions there were ash stands of different age, with ash being the principal species with wych elm (*Ulmus glabra*), aspen (*Populus tremula*), alder (*Alnus glutinosa*), and silver birch (*Betula pendula*) admixture; in several units ash was the admixture species for birch, spruce etc. forests. Both regions are characterized by fertile development conditions, mostly *Aegopodiosa*, on rare occasions *Dryopteriosa* or *Mercurialiosa* ameliorated forest types, characterized by various broad leaved species.

In each unit one 20×20 m plot was established, and the projective cover percentage of the first (E3, above 7.0 m) and second (E2, 0.5 – 7.0 m) layer of each species was determined. In each plot, all advance regenertion and undergrowth species (up to 7.0 m) were counted and degree of ash damage by *H. fraxineus* (Table 1) was determined in the framework of five classes along a diagonal 25×1 m transect. *H. fraxineus* damage has been assessed according to the visually determined degree of damage of the tree crown and trunk. The final rating was assigned based on the number of woody plants in each damage class. If there were no new specimens found in the transect, the degree of damage was not established. Twenty eight units were surveyed in Skrīveri and 73 units in Bērvircava.

GRF formation criteria were used as the basis for evaluation of forest quality (Koskela et al., 2013), supplemented by the descriptors listed in the report by A. Gailis et al. (2008). After a complex evaluation, each region was given a quality rating in classes from 1 to 5. The number of classes was determined based on the number of descriptor classes in the research made in Latvia (Gailis et al., 2008). The descriptors are divided into two groups: primary (if all descriptors were given equal rating – quality class could be established without taking into account other descriptors), corresponding to GRF formation basic requirements, and secondary – derived from A. Gailis et al. (2008) (Table 1). Criteria class values have been established according to median, quartile, minimum and maximum values of the evaluations obtained in all samples. In ash regeneration and E3 covering class division, Pan-European minimum requirements have been taken into account, stipulating that for an ash stand to be qualified as a GRF at least 50 mature trees and 400 saplings per hectare are required (Koskela et al., 2013). Based on these rules, it was supposed that the minimum number of advance regeneration ash trees has to be above 800 trees per hectare to qualify as a GRF (Table 1).

Tree level dominance structure has been established according to the principle of dominant and codominant species (Simpson, 2006), where the dominant species comprise ≥ 50% of the total covering or at least exceeds the covering of other species by 20%, and the codominant species is 25 – 50% of the total cover. Vegetation description and growth inventory was done during the 2014 growing season.

In characterizing unit similarities and factors having influence upon them, the detrended correspondence analysis (DCA) method was used. In determining which factors best characterize fluctuation, principal component analysis (PCA) was carried out, the second matrix being basic criteria for GRF selection. Thus criteria were obtained that most precisely characterized forest unit quality; they were taken into account upon determining quality classes. The canopy dominant species' influence on advance regeneration and undergrowth content was analysed by using the DCA method. In determining gradient importance, a randomization test was used for both methods.

The correlation between the degree of ash damage by *H. fraxineus* and the dominant tree species, forest type, new ash advance regeneration density (in classes), shrub layer cover and ash cover in E3 layer, was determined by the general linear model (GLM) method. Analysis of variance (ANOVA) was used to determine whether the number of ash in advance regeneration has been significantly influenced by the forest type and dominant tree species. For the evaluation of ash advance regeneration density, tree and shrub layer projective cover as well as correlations between the number of other species listed in advance regeneration and undergrowth, Pearson and Kendall correlation analysis was carried out. By using the Kendall ratio, it was determined if there was a correlation between shrub layer cover and the number of ash trees in layers E3 and E2. The analyses were carried out at α = 0.05. Statistical analyses were made using PC-ORD 6 (Peck, 2010) and R computer programmes.

Results and Discussion

In the majority of GRF units, ash trees were found in admixture with other broad leaved species, complying with ecological requirements (Ahlberg, 2014). In Skrīveri the E3 layer was dominated by birch (29% of units), small-leaved lime (*Tilia cordata*) and elm (both 14%), whereas in Bērvircava it was dominated by ash (27%) and aspen (21%) (Figure 1). In Latvia the following species are recommended as ash satellite species: birch, alder, grey alder (*Alnus incana*) and pedunculate oak (*Quercus robur*) (Sakss, 1997). Apart from these species, lime and elm are also emphasised in Europe (Dobrowolska et al., 2008), although ash trees in elm forests in Latvia have seldom regenerated, based on previous research (Laiviņš and Mangele, 2004). In Skrīveri, the most common broad leaved tree species are the typical *Aegopodiosa* forest site type species - lime, elm and ash. Analysis of variance indicated that ash regeneration density in Skrīveri has been significantly influenced by the dominant species in layer E3 (p = 0.001) and forest type (p = 0.03), whereas in Bērvircava none of these factors was decisive. In the framework of this research, ash was regenerated best in *Aegopodiosa* and *Mercurialiosa* mel. forest site types, namely, in habitats that are rich in nutrients, biologically active,

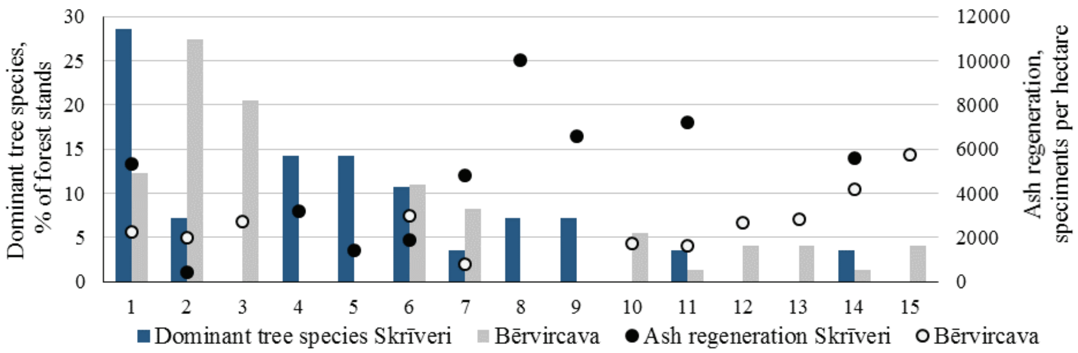

Figure 1. Dominant tree species and ash saplings density: 1 – *Betula pendula*; 2 – *Fraxinus excelsior*; 3 – *Populus tremula*; 4 – *Tilia cordata*; 5 – *Ulmus glabra*; 6 – *Alnus incana*; 7 – *Picea abies*; 8 – *Betula pendula/Ulmus glabra*; 9 – *Fraxinus excelsior/Ulmus glabra*; 10 – *Alnus incana/Fraxinus excelsior*; 11 – *Alnus incana/Betula pendula*; 12 – *Betula pendula/Populus tremula*; 13 – *Betula pendula/Fraxinus excelsior*; 14 – *Alnus glutinosa*; 15 – *Quercus robur.*

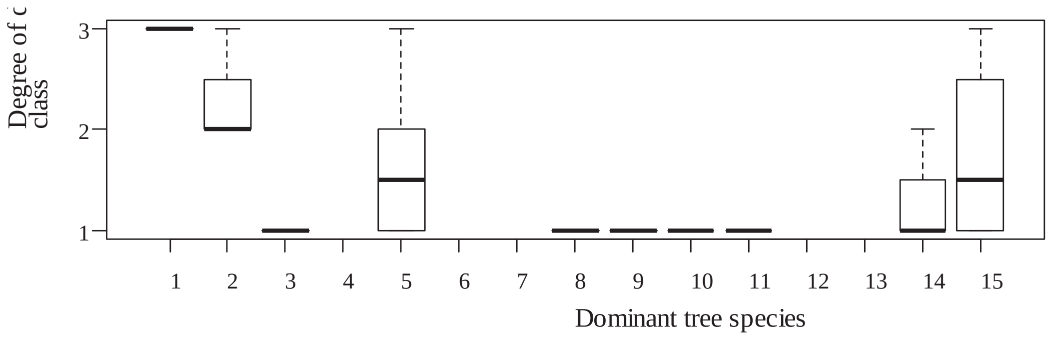

Figure 2. Ash advance regeneration damage degree intensity in stands with different dominant species in Skrīveri: 1 – *Alnus* glutinosa; 2 – Alnus *incana;* 3 – *Alnus incana/Betula pendula*; 4 – *Alnus incana/Fraxinus excelsior*; 5 – *Betula pendula*; 6 – *Betula pendula/Fraxinus* excelsior; 7 – Betula *pendula/Populus tremula*; 8 –*Betula pendula/Ulmus* glabra; 9 – *Fraxinus excelsior*; 10 – *Fraxinus excelsior/Ulmus* glabra; 11 – *Picea abies*; 12 – *Populus tremula*; 13 – *Quercus robur*; 14 – *Tilia cordata*; 15 – *Ulmus glabra.*

moist and seasonally excessively moist, but it was not as successful regenerating in *Dryopteriosa*, as has previously been mentioned in other research carried out in Latvia (Laiviņš and Mangele, 2004; Kenigsvalde et al., 2010).

Better and more regular ash regeneration was observed in Skrīveri, where, in the framework of this research, the greatest number of ash specimens were found in birch/elm (10 000 trees ha^{-1}) and grey alder/birch (7 200 trees ha^{-1}) stands (Figure 1). In ash/elm mixed stands, 6 600 trees ha^{-1} were counted. In Bērvircava the best ash regeneration was observed in oak (7 400 trees ha^{-1}) and alder (4 200 trees ha^{-1}) stands. Ash regeneration below ash stands was not characteristic of any region, but it was higher in Bērvircava (2 000 trees ha^{-1}) (Figure 1).

GLM analysis showed that in Skrīveri the new ash advance regeneration degree of damage was statistically significantly different between stands with various dominant species. In Skrīveri the highest degree of damage of new ash trees was found in alder stands ($p = 0.0004$) (Figure 2). The second class damage degree was found in grey alder, but a higher degree of damage was also found in birch and elm stands. In Bērvircava ash trees damage degree was much lower and statistically did not differ between stands with various dominant species.

In DCA both locations were firstly divided by their different geographical position, because they are situated in differing geobotanical regions. In DCA all gradients were important and they showed that areas differed in canopy composition, and it had significant impact on ash regeneration density, as mentioned in research by M. Laiviņš and D. Mangale (2004). The DCA first variable was best characterized by grey alder and aspen (DCA1) ($p = 0.02$), the second by spruce (DCA2) ($p = 0.03$), and the third by ash together with oak (Figure 3).

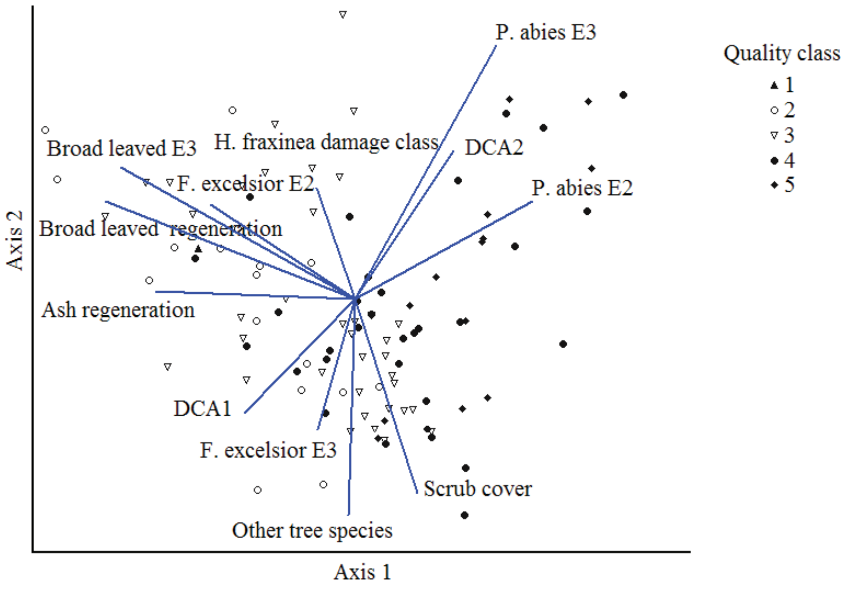

Figure 3. Ash forest quality criteria in PCA analysis.

Ash regeneration density had a statistically significant correlation with a number of woody plants listed in advance regeneration in Bērvircava (p = 0.03, τ = 0.184), confirming the previous research in Latvia which showed that regeneration of ash and other woody plants most often takes place in canopy and thinned out places (Sakss, 1997). In Bērvircava two tree species dominated the advance regeneration composition – grey alder (55% of the total number of species, 3 704 trees ha^{-1}) and ash (34%, 2 290 trees ha^{-1}) (Figure 4). Formation of pronouncedly mixed stands with elm (58%, 4 243 trees ha^{-1}), ash (29%, 4 214 trees ha^{-1}), lime (17%, 2 514 trees ha^{-1}) and Norway maple (*Acer platanoides*) (16%, 2 329 trees ha^{-1}) is typical of Skrīveri. Species composition corresponds to the species listed in ash clear-cuts in Lithuania, only the cover was different: birch (in Lithuania – 32.9%), grey alder (32.4%), aspen (11.2%), elm (6.4%) and ash (4.3%, but 13 941 trees ha^{-1}) (Lygis et al., 2014). The results of this research indicated that pure ash stands are not formed by means of natural regeneration, but in both locations ash is maintained as an admixture species. In research by Laiviņš and Mangele (2004) it is foreseen that ash will be maintained in tree layer as a permanent admixture only on average in 5% of broad leaved forests. In Skrīveri the same species regenerate that dominate layer E3 (lime, elm), the same correlation has also been observed in Lithuania (Lygis et al., 2014). Whereas in Bērvircava, where the dominant species is ash, undergrowth species regenerate - hazel (*Corylus avellana*) and bird cherry (*Padus avium*), indicating the beginning of a pronounced process of shrub overgrowth.

In Skrīveri three species were dominant in undergrowth: cherry (39%, 1 071 trees ha^{-1}), hazel (33%, 914 trees ha^{-1}) and fly honeysuckle (*Lonicera xylosteum*) (21%, 586 trees ha^{-1}), but in Bērvircava - cherry (63%, 12 433 trees ha^{-1}) and hazel (20%, 3 945 trees ha^{-1}) (Figure 4). Although hazel is considered a valuable ash forest species (Loidi, 2004), together with cherry they comprised more than 50% of all species composition in both areas, thus leaving little room for growth to other species. The correlation indicated that as the shrub layer cover increases, the density of new ash trees decreases, but statistically it was not significant. Research carried out in Denmark (Bakys et al., 2013) showed that there is greater degree of ash damage in thinned stands, but it is not correlated with ash tree density. In the present research, identical results were obtained, although in Skrīveri it was found out that a higher degree of damage (class 2) can be established in stands with denser shrub cover (Figure 5), in several plots, the degree of damage reached class 3 and 4 in units with greater ash density, but the correlation was not significant. On average, the degree of damage was lower than indicated in the Lithuanian research (Lygis et al., 2014), because 80.8% were rated as class 1,while in Lithuania only 29.3% were considered visually healthy (Lygis et al., 2014). It could not be established that the degree of ash damage is significantly influenced by ash cover in the tree layer, but in stands with greater ash cover, more often a higher regeneration growth degree of damage was found.

GLM analysis showed that statistically the new ash advance regeneration degree of damage does not differ significantly among forest types. The lowest new ash advance regeneration's degree of damage was established in *Mercurialiosa* mel. forest site type (p=1.26E-05), where it was not higher than class 1 in any of the units. The highest degree of damage was established in *Dryopteriosa* forest site type (most often class 2). Although there is no united opinion in Europe on whether there is a correlation between ash degree of damage and the ecological conditions in the

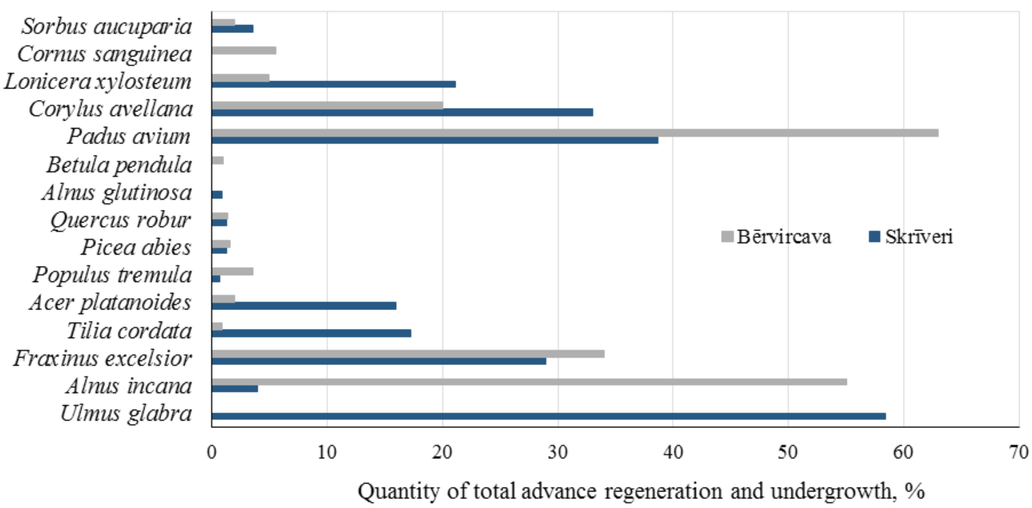

Figure 4. Species composition in advance regeneration and undergrowth.

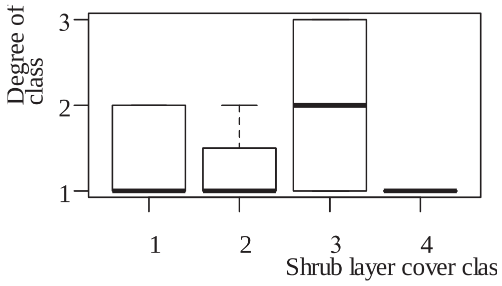

Figure 5. Ash degree of damage depending on shrub layer density in Skrīveri.

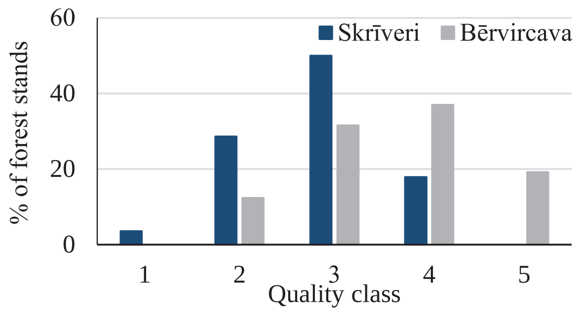

Figure 6. Ash GRF quality evaluation in classes.

locations (Bakys et al., 2013), this research shows that there is a higher degree of damage by *H. fraxineus* in moist circumstances than indicated in A. Gross's research (Gross et al., 2014).

According to the basic criteria for GRFs, the Skrīveri plots corresponded to higher quality classes. In both locations ash regeneration density was statistically significantly influenced by the total canopy cover ($p = 0.02$, $\tau = 0.16$) confirming that ash during its first years of life is ombrophile (Dobrowolska et al., 2008). In research by R. Harmer et al. (2005) it was concluded that the number of ash seedlings was positively related to the number of parent trees, which was also confirmed during this research ($p = 0.001$, $\tau = 0.22$). The number of ash trees in any of the regions was not influenced by DCA1 variable grey alder/ aspen ($p>0.05$), but it negatively influenced the number of spruce in layers E3 and E2. It was more pronounced in Bērvircava ($p = 0.02$, $\tau = -0.2$), confirming that spruce in Latvia is not recommended as an ash satellite species because it decreases soil productivity and creates a strong root system which outcompetes ash (Sakss, 1997). Ash regeneration was strongly influenced by the number of broad leaved species in layer E3 ($p = 0.005$, $\tau = 0.21$) emphasizing the importance of mixed stands (Ahlberg, 2014).

The PCA of all criteria showed that without GRF basic criteria ash stand variation is also well characterized by spruce cover in layers E3 and E2, the total cover of layer 2 and undergrowth layer, DCA1, the number of broad leaved species in layer E3 and other criteria (Figure 3). However, the correlations of these variables with ash regeneration density indicated that DCA1 and the number of broad leaved species do not have a significant impact. Evaluating all criteria (Table 1) better forest condition was found in Skrīveri, where 50% of units were rated with the quality class 3 and there were no evaluations of the lowest class 5 (Figure 6). In Bērvircava, 19% units were rated with class 5 and a relatively similar number of units were rated with class 3 and 4. In several units ash trees have not been maintained neither in layer E3 nor layer E2. In both GRFs, the new ash is mostly young and it is difficult to foresee its further development as well as changes in the evaluation of stands.

Conclusions

1. In the beginning, 12 quality indicators were set for GRF quality evaluation, out of which during the research only 9 were recognized as significant, 3 of them (ash projective cover in canopy and midstorey, ash regeneration density) are considered primary, others have a secondary importance.
2. In the majority of stands, ash is not the dominant species anymore, but a statistically significant correlation remains, namely, ash regenerate best in stands with greater ash projective cover in the canopy, although the number of specimens is comparatively small (2000 trees ha^{-1} in Skrīveri, 400 trees ha^{-1} in Bērvircava).
3. In stands where ash was the dominant species prior to ash dieback, intense shrub overgrowth has started, indicating that change of species is significantly influenced by dominant tree layer species which is typical of *F. excelsior* stands.
4. Ash stand destruction in both regions developed differently. Although ash is better maintained in Bērvircava, the overall state of GRF stands was recognized as worse there, and 19% of units do not comply with GRF criteria anymore.

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