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The population structure and regeneration of *Sorbus torminalis* in Hádecká planinka National Nature Reserve (Czech Republic)

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Abstract: We performed a detailed overall field survey of all specimens of the wild service tree *Sorbus torminalis* (L.) Crantz in the research area in the Hádecká planinka National Nature Reserve. This research area, with an area of 80 ha, contains one of the largest populations of the tree in Europe. In all, 1713 specimens were found. This study provides a detailed description of the wild service tree population in the area. The basic biometric parameters (height, GBH, social position, fertility) of the population were assessed. The main emphasis of our analysis was to evaluate the population's age structure. We used estimates of age structure based on the Chapman-Richards growth function to perform this evaluation. During the past twenty years, the natural regeneration of the wild service tree in the nature reserve has decreased considerably. At an experimental plot where a high forest was converted to a coppice with standards, regeneration occurred over 75% of the area. Root suckers were found at the beginning of the observation period. After 2–3 years, generative regeneration occurred.

Additional key words: wild service tree, age structure, forest systems, species protection

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Introduction

The wild service tree is a typical forest companion species with a scattered distribution in the Czech Republic (Kovanda 1992). No study addressing the population structure of the wild service tree has been published to date in the Czech Republic. Surprisingly few studies mention the species. Such studies either simply note the occurrence of the wild service tree (Velička 1993, Čeřovský et al. 2007, Dostál, 2002, Fiedler 1974, Hofmeister 2001, Kovanda 2000, Lepší et al. 2009, Sedláčková and Lustyk 1999) or describe the distribution of the species in a limited area (Šefl 2007, Zahradová 1988). Studies assessing the species from a forestry perspective are published only rarely (Prudič 1998, Hurt and Kantor 2004). In contrast, research on the wild service tree at the population level is very frequent outside the Czech Republic. For example, previous studies have appeared from Poland (Bednorz et al. 2006), Italy (Belletti et al. 2008), Germany, Switzerland and Denmark (Angelone et al. 2007, Rasmussen 2007, Rasmussen and Kollmann 2007, Hoebee et al. 2006), Austria (Hochbichler 2003) and the Slovak Republic (Paganová 2007).

In Central Europe, populations of *S. torminalis* are scattered, often small (100 individuals) and spatially isolated (Hoebee et al. 2007). For example, this tree is classified as an endangered species in the Czech Re-

public (CR) (Úradníček et al. 2010). In Poland, it is protected by law (Bednorz 2007b).

This study describes and evaluates the population structure of the wild service tree in the Hádecká planinka National Nature Reserve, which contains one of the largest populations within the natural range of the species. One of the aims of the research was to evaluate the behaviour of the population in the reserve, where management excluding human influence has been applied for 60 years and whose forest communities consist of irregular stemwood of coppice origin. We also explored the ability of the wild service tree to regenerate naturally during conversion to a coppice with standards and to a coppice forest.

Methods

Study area

The Hádecká planinka National Nature Reserve is located at the northeastern edge of the city of Brno in the CR and is a southern protrusion of the Moravian Karst Landscape Protected Area. This reserve is located on a karst tableland at an altitude of approximately 420 m and has an area of approximately 80 ha; the mean annual temperature is 8.4°C, and the mean annual precipitation is 531 mm (data from the Brno climate monitoring station). The geological background is Devonian limestone in plateaus covered by loess loam of various thicknesses. The forest occupies nearly the entire area of the reserve, and the predominant woody species are *Quercus petraea* agg., most often *Q. dalechampii* (63%), and *Carpinus betulus* (22%). The other woody species appear as admixtures, with *Sorbus torminalis* representing 1.68% according to the forest management plan. The stands are of coppice origin and were gradually converted to irregular stemwood by thinning out trunks of coppice origin during the first half of the 20th century. Since 1950, when the area was declared a nature reserve, management excluding human influence has been applied to study the spontaneous development of the forest communities. The forests are the property of Mendel University in Brno.

Field work

The area of the reserve was inventoried with a field survey, and the position of each individual of the wild service tree was surveyed using GPS (Trimble Juno SB) and given an ordinal number. The following data were recorded for all individuals: girth at breast height (GBH) (measured with a tape) and total height (by TruePulse); height of the crown base (from the tree base to the first strong branch); fertility according to a three-level semiquantitative scale (very fertile, fertile and infertile trees); and position in the stand, in accordance with the classification introduced by Konšel (1931), as dominant, co-dominant, intermediate, shaded viable, dead or dying trees.

In addition, a core was taken at breast height with a Pressler borer from 47 individuals of various GBH classes with a range of girths from 26 to 155 cm to establish the ages of these groups.

Laboratory analyses

The tree rings in the core samples were analysed with a stereo magnifier on a measuring table with a shifting top. The analysis was conducted with PAST 32 software.

The age structure of the population was then established by the Chapman-Richards growth function as follows:

$$y = A * \left[1 - e^{-b*x}\right]^{1/c}$$

The calculations were based on the true age determined for the 47 individuals with various stem girths.

Wild service tree regeneration

The regeneration of the wild service tree was evaluated in an experimental plot adjacent to the Hádecká planinka National Nature Reserve. In this plot, a high forest was converted to a coppice with standards. The fenced 4-ha research area was divided into 16 squares (50 m by 50 m). Four different treatment intensities were applied, and four replicates were used. The shrub layer was removed, and the tree layer was reduced by 100%, 77%, 63% and 54% of the stem volume (Kadavý et al. 2011). In each square, a permanent phytocoenological plot was established in 2008, and phytocoenological relevés were recorded to document the condition of the forest before the treatment. Afterwards, phytocoenological relevés were recorded yearly to document the condition of the forest after each treatment series. The series of relevés was used to evaluate the regeneration of the wild service tree in the plot converted to coppice with standards.

Results

The population structure of the wild service tree in the Hádecká planinka National Nature Reserve

In the 80-ha Hádecká planinka National Nature Reserve, 1713 specimens of the wild service tree were found (Fig. 1). The surrounding stands, where the tree is present in similar numbers, also require consideration. The population density was 21.4 trees per hectare. The structure of the population in terms of the stem girth and tree height is shown in figures 2 and 3. The most frequently represented trees are 20–60 cm in circumference, and the maximum recorded stem diameter was 50 cm. The height of the

Fig. 1. The distribution of 1713 specimens of the wild service tree in the Hádecká planinka National Nature Reserve. The colours express different stem diameter

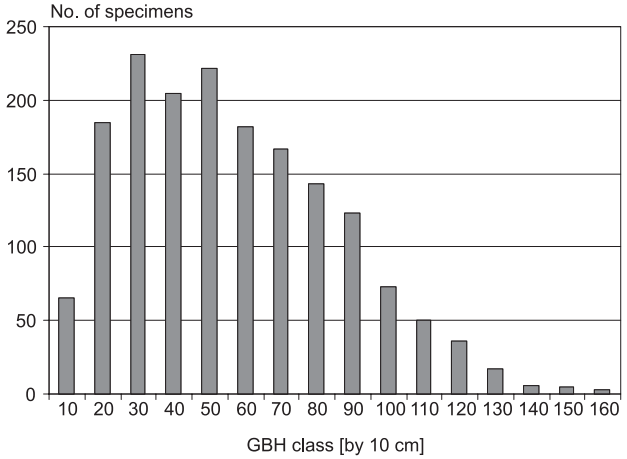

Fig. 2. Numbers of specimens of the wild service tree in the Hádecká planinka National Nature Reserve by GBH class

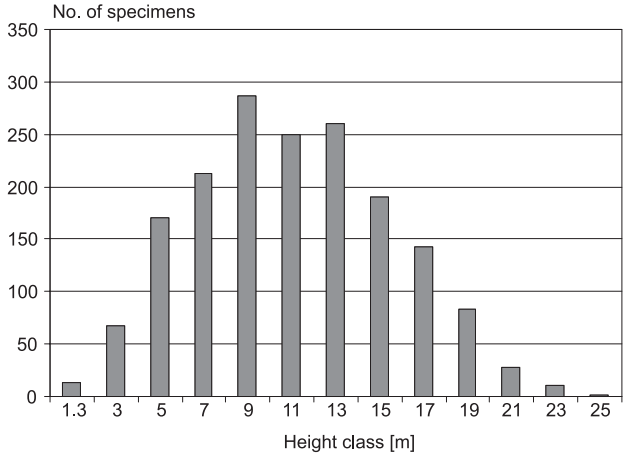

Fig. 3. Numbers of specimens of the wild service tree in the Hádecká planinka National Nature Reserve by height class

population is normally distributed and ranges from 0.5–25 m. The social characteristics of the trees indicated that 38.7% of the specimens are intermediate trees and 33.98% of the specimens are co-dominant trees. Moreover, 22.24% are shaded but viable specimens, 3.04% are dominant trees and 2.04% are dead or dying specimens. During the year of the study, 65% of the specimens had no fruits and 35% bore fruits. Of the fruit-bearing trees, 2% had a large number of fruits. These trees were always peripheral and dominant. The social characteristics determined for these trees indicated that 81% of the fruit-bearing specimens were dominant or co-dominant and 19% were intermediate or dying.

To estimate the age structure of the population, the Chapman-Richards growth function was calculated as follows:

$$y = 712.12278 * \left[1 - e^{-0.0016141 * x}\right]^{1/0.8933935}$$

This calculation expresses the dependence of the age of a specimen (y) on its girth at breast height (x) (Fig. 4). The ages of all individuals in the population

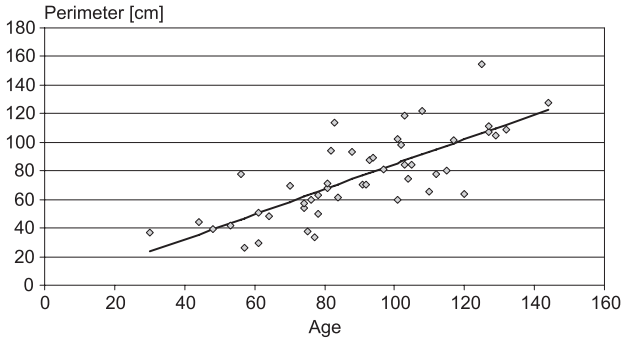

Fig. 4. Non-linear regression (CH-R growth function) between stem girth and age in the population of the wild service tree in the study area, all parameters are statistically significant, $P<10^{-7}$, $R^2=0.586$ determination index 0.765, n = 47, asymptote fixed at 712

Fig. 5. Age structure of the population of the wild service tree in the Hádecká planinka National Nature Reserve

were estimated and represented with this equation (Fig. 5). The graph shows that specimens aged 20 to 70 occur in equal proportions and at the highest frequencies in the population; with increasing age, the proportion of specimens in the population decreases gradually. The first two age classes, representing trees less than 20 years of age, occur at low frequencies. The decrease in natural regeneration over the past 20 years was most likely caused by the closing of formerly open stands and the intense development of the shrub layer in the reserve through a process of spontaneous succession. At the time of this study, only 13 individuals with a height less than 1.3 m were found.

Regeneration of the wild service tree

The regeneration of the wild service tree in the Hádecká planinka experimental plot in association with the conversion of a high forest to a coppice with standards occurred in 75% of the phytocoenological relevés in 2011, three years after treatments of various intensities. In 2008, in the closed forest before the treatment, the regeneration of the wild service tree was observed in only one plot in the herb layer and three plots in the shrub layer. In spring 2009, after the treatment, regeneration was observed at four plots in the herb layer. The shrub layer had previously been extracted. Natural regeneration then increased during each of the following years. Natural regeneration occurred in up to eight plots in the herb layer and 2 plots in the shrub layer in 2010 and in up to 12 plots in the herb layer and 3 plots in the shrub layer in 2011. Where specimens were cut, root suckers formed immediately, and generative regeneration was evident after 2 to 3 years.

Discussion

According to the most recent inventory in Poland, the wild service tree occurs at 73 natural sites, and its population does not exceed 2500 individuals (regeneration not included). Local populations are small, and only 8 sites have more than 100 trees (Bednorz 2007b). Müller et al. (2000) recorded 76 trees, with an area of 0.6 ha, at their experimental plot near Bamberg in Bavaria, Germany; however, the plot has an area of only 3 ha. Belletti et al. (2008) describe 22 populations in Italy, with a density of 5–40 specimens per hectare. Out of 19 populations in Germany, Switzerland and Denmark, only 7 contain more than 100 specimens, with a maximum of 1000 (Rasmussen 2007). The Rambouillet forest near Paris, the study area of Oddou-Muratorio et al. (2005), with a size of 485 ha, had 185 mature trees (more than 5 cm in diameter). Angelone et al. (2007) studied 26 populations in Switzerland, with 16–532 individuals; however, one population had 2000 specimens. In Switzerland, Hoebee et al. (2006) recorded data for 10 populations, with 13–143 individuals. In another study (Hoebee et al., 2007), these authors investigated 2 populations; one had 96 individuals in an area of 18 ha, and the other had 27 individuals in an area of 2 ha. At the northern limit of the species' distribution in Denmark and northern Germany, 14 populations are known; the species occurs in small populations of 3–300 specimens on islands in the Baltic Sea (Rasmussen and Kollmann 2007). This scattered species combines an extensive range with low local density, usually less than one individual per hectare (Oddou-Muratorio et al. 2005). In addition, Demesure et al. (2000) reported that the species occurs at low densities of 0.1–30 individuals per ha. In this context, the population in the Hádecká planinka National Nature Reserve and the surrounding stands is one of the most extensive populations in Central Europe, with a relatively high density comparable to that of the population investigated by Hochbichler (2003) in Austria. The density of this Austrian population is 36 trees per hectare (dbh > 7 cm) in an area of about 130 ha.

The age structure of wild service tree populations is addressed by Rasmussen and Kollmann (2007), who find that the largest proportion of specimens occurs in the youngest age classes (up to 20 years of age) in five populations. This aspect of age structure differs completely from that found in the population of the Hádecká planinka National Nature Reserve, in which the number of specimens aged 10–20 is less than the number of specimens in the other age classes and the number of specimens below 10 years of age is negligible. In this reserve, the management policy based on the exclusion of human influence that has been applied to study the spontaneous succession of communities of thermophilic oak stands can lead to a gradual decline of the wild service tree. The reason for the decline is the gradual closing of a formerly open stand and the creation of a thick shrub layer. These changes decrease the proportion of light entering the stand. Under these conditions, the wild service tree does not regenerate and is less fertile. Because only the trees that grow at the stand edges are prolific, this characteristic considerably increases the significance of these habitats (Škodová and Gajdoš 2011). No immediate risk is involved, however. Hurt and Kantor (2004) recorded ages ranging from 136 to 389 years for wild service trees in forest stands in the Křivoklátsko region. In contrast, the wild service trees in the study area are much younger. These younger ages imply that the population of these trees in the study area is not threatened. A possible solution is to define a sufficiently large buffer zone within the reserve to manage as a coppice with standards. The ecological requirements of the wild service tree are entirely satisfied only under management as a coppice with stan-

dards. This very favourable opinion is shared by many foresters interested in the ecology and silviculture of wild service trees (Nicolescu et al. 2009). The conversion of high forest to coppice with standards is vegetative at first. After 2–3 years, this treatment also produced generative regeneration of the wild service tree. Rasmussen and Kollmann (2004) observed an absence of generative regeneration at the edge of the natural range of the wild service tree. Generative regeneration was replaced by regeneration via root suckers. If regeneration is insufficient, as certain authors have observed (e.g., Biedenkopf et al. 2007), we can also introduce plants from seeds (Bednorz 2007a, Takos and Efthimiou 2003). Furthermore, in vitro propagation procedures have been studied (Malá et al. 2009). Natural regeneration from seeds can be endangered by competition from faster-growing woody plants (Collet et al. 2008), massive feeding on seeds by rodents (Velička 1993) and browsing by ungulates (Biedenkopf et al. 2007, Collet et al. 2008), although Boulanger et al. (2009) classify the wild service tree among the plants least endangered by browsing. The growth of saplings appears to be a more troublesome issue. Sapling growth is most likely limited by an insufficient supply of light under closed canopies (Kausch-Blecken 1994, Müller et al. 2000, Rasmussen 2007, Paganová 2007, 2008). According to Nicolescu et al. (2009), newly germinated seedlings require full overhead light. Otherwise, they soon disappear. Few examples of the successful regeneration of the wild service tree from seeds are documented. However, Bednorz et al. (2012) describes a population density of up to 337 young trees per hectare in a study plot in the Jamy Forest District, and Hochbichler (2003) counted up to 850 trees per hectare in a young stand in an area of about 130 ha managed as a coppice with standards.

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References

Angelone S., Hilfiker K., Holderegger R., Bergamini A., Hoebee S.E. 2007. Regional population dynamics define the local genetic structure in *Sorbus torminalis*. Molecular Ecology 16: 1291–1301.

Bednorz L., Kaźmierczak K., Kaczmarek L. 2012. Analyses of spatial structure and selected measures of growth of *Sorbus torminalis* in Forest District Jamy (northern Poland). Dendrobiology 67: 59–65.

Bednorz L. 2007a. Morphological variability of fruits and seeds of *Sorbus torminalis* in Poland. Dendrobiology 57: 3–14.

Bednorz L. 2007b. Conservation of genetic resources of *Sorbus torminalis* in Poland. Dendrobiology 58: 3–7.

Bednorz L., Myczko L., Kosinski P. 2006. Genetic variability and structure of the wild service tree (*Sorbus torminalis* (L.) Crantz) in Poland. Silvae Genetica 55 (4–5): 197–202.

Belletti P., Monteleone Ć I., Ferrazzini Ć D. 2008. A population genetic study in a scattered forest species, wild service tree [*Sorbus torminalis* (L.) Crantz], using RAPD markers. European Journal of Forest Research 127:103–114.

Boulanger V., Baltzinger Ch., Saïd S., Ballon P., Picard J-F., Dupouey J-L. 2009. Ranking temperate woody species along a gradient of browning by deer. Forest Ecology and Management 258: 1397–1406.

Collet C. , Piboule A., Leroy O., Frochot H. 2008. Advance *Fagus sylvatica* and *Acer pseudoplatanus* seedlings dominate tree regeneration in a mixed broadleaved former coppice-with-standards forest. Forestry 81: 135–150.

Čeřovský J., Podhajská Z., Turoňová D. 2007. Botanicky významná území ČR. Agentura ochrany přírody a krajiny ČR, Praha, pp. 407.

Demesure B., Le Guerroué B., Lucchi G., Prat D., Petit R-J. 2000. Genetic variability of a scattered temperate forest tree: *Sorbus torminalis* L. (Crantz). Annals of Forest Science 57: 63–71

Dostál P. 2002. Jarní návštìva Pavlovských vrchù. Živa, 50 (2): 90–93.

Fiedler J. 1974. Příspěvek k floristicko – fytocenologickému průzkumu lesů mezi Chlumcem nad Cidlinou a Bohdancem. Zprávy Československé botanické společnosti, 5: 39–52.

Hoebee S.E., Arnold U., Düggelin C., Gugerli F., Brodbeck S., Rotach P., Holderegger R. 2007. Mating patterns and contemporary gene flow by pollen in a large continuous and a small isolated population of the scattered forest tree *Sorbus torminalis*. Heredity 99: 47–55.

Hoebee S.E., Menn C., Rotach P., Finkeldey R., Holderegger R. 2006. Spatial genetic structure of *Sorbus torminalis*: The extent of clonal reproduction in natural stands of a rare tree species with a scattered distribution. Forest Ecology and Management 226: 1–8.

Hofmeister J. 2001. Jak si stojí dubohabrové lesy v CHKO Český kras. Živa, 49 (3): 111–112.

Hochbichler E. 2003. Die Elsbeere (*Sorbus torminalis* Crantz) im Weinviertel (Niederösterreich). Forst und Holz 58: 647–653.

Hurt V., Kantor P. 2004. Jeřáb břek (*Sorbus torminalis* (L.) Crantz), opomíjená cenná listnatá dřevina a její význam na Křivoklátsku. In: Conference Proceedings: Woody plants and forest soil – biological melioration and its uses. Kostelec nad Černými lesy, ČZU Prague, pp. 40–48.

Kadavý J., Kneifl M., Knott R. 2011. Establishment and selected characteristics of the Hády coppice and coppice-with-standards research plot (TARMAG I). Journal of Forest Science, 57: 451–458.

Kausch-Blecken von Schmelling W. 1994. Die Elsbeere (*Sorbus torminalis* (L.) Crantz). Bovenden, Verlag Kausch, pp. 253.

Konšel J., 1931. Stručný nástin tvorby a pěstění lesů v biologickém ponětí. Česká matice lesnická, Písek, pp. 543.

Kovanda M. 1992. *Sorbus* L. – jeřáb. In: Květena České republiky 3. Hejný S., Slavík B. (eds.). Academia, Praha, pp. 474–484.

Kovanda M. 2000. Jeřáby v Praze. Živa. 48 (1): 12–13.

Lepší M., Kaplan Z., Lepší P. 2009. *Sorbus gemella* Kovanda. Severočeskou přírodou: sborník Severočeské pobocky Československé botanické společnosti 40: 122–126.

Malá J., Máchová P., Cvrčková H., Karady M., Novák O., Mikulík J., Hauserová E., Greplová J., Strnad M., Doležal K. 2009. Micropropagation of Wild Service Tree (*Sorbus torminlais* [L.] Crantz): The regulative role of different aromatic cytokinins during organogenesis. Journal of Plant Growth Regulation 28: 341–348.

Müller S., Ammer C., Nosslein S. 2000. Analyses of stand structure as a tool for silvicultural decisions – a case study in a *Quercus petraea – Sorbus torminalis* stand. Forstwissenschaftliches Centralblatt 119: 32–42.

Nicolescu V.N., Hochbichler E., Coello Gomez J., Ravagni S., Giulietti V. 2009. Ecology and silviculture of wild service tree (*Sorbus torminalis* (L.) Crantz): A literature review. Die Bodenkultur – Journal for Land Management, Food and Environment 60: 35–44.

Oddou-Muratorio S., Klein E.K., Austerlitz F. 2005. Pollen flow in the wildservice tree, *Sorbus torminalis* (L.) Crantz. II. Pollen dispersal and heterogeneity in mating success inferred from patent – offspring analysis. Molecular Ecology 14: 4441–4452.

Paganová V. 2007. Ecology and distribution of *Sorbus torminalis* (L.) Crantz in Slovakia. Horticultural Science 34: 138–151

Paganová V. 2008. Ecological requirements of wild service tree (*Sorbus torminalis* [L.] Crantz) and service tree (*Sorbus domestica* L.) in relation with their utilization in forestry and landscape. Journal of Forest Science 54: 216–226.

Prudič Z. 1998. Růst a rozšíření jeřábu oskeruše a břeku v Moravských Karpatech. Lesnictví 44 (1): 32–38.

Rasmussen K.K. 2007. Dendroecological analysis of a rare sub-canopy tree: Effects of climate, latitude, habitat conditions and forest history. Dendrochronologia 25: 3–17

Rasmussen K.K., Kollmann J. 2004. Poor sexual reproduction on the distribution limit of the rare tree *Sorbus torminalis*. Acta Oecologica 25: 211–218.

Rasmussen K.K., Kollmann J. 2007. Genetic diversity, spatial patterns, and growth of root sprouts in a temperate tree at the northern distribution limit. Écoscience 14: 250–258.

Sedláčková M., Lustyk K. 1999. Přispěvek ke květeně Vidnavského výběžku (SZ Slezsko). Časopis Slezského muzea v Opavě. A: Vědy přírodní, 48: 209–222.

Šefl J. 2007. Rowans in the Podyjí National Park. Thayensia (Znojmo) 7: 121–151.

Škodová M., Gajdoš A. 2011. Anthropogenically created forest edge in the Starohorské vrchy Mts. on the example of Donovaly village. Journal of Landscape Ecology, 4: 55–64.

Takos I.A., Efthimiou G. SP. 2003. Germination Results on Dormant Seeds of fifteen Tree Species Autumn Sown in a Northern Greek Nursery. Silvae Genetica 52: 67–71.

Úradníček L., Maděra P., Tichá S., Koblížek J. 2010. Woody plants of the Czech Republic. Lesnická práce, Kostelec nad Černými lesy, pp. 368.

Velička M. 1993. Dnešní výzkum původních dřevin na severovýchodní Moravě. Časopis Slezského muzea v Opavě. A: Vědy přírodní, 42: 187–191.

Zahradová S. 1988. Vyhodnocení výskytu a lesnického významu břeku (*Sorbus torminalis* Crantz) na jižní Moravě. Thesis, VŠZ, Brno, pp. 95.