

The relations between extractives and ash contents, annual rings width, share of latewood and hydrogen phosphate and sulphate anions concentrations in the wood and bark of the *Pinus sylvestris* L. stem

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Abstract

Extractives and ash contents, share of latewood and annual rings width were analyzed in wood at different heights and different zones of the *Pinus sylvestris* L. stem cross-section. Additionally, the high performance liquid chromatography (HPLC) with a conductometric detector was applied to determine the sulphate (SO_4^{2-}) and hydrogen phosphate (HPO_4^{2-}) anions concentrations in wood and bark of *Pinus sylvestris* L. stem. Our results showed that the higher share of latewood in annual rings the lower ash and extractives contents in the wood, but the higher sulphate (SO_4^{2-}) and hydrogen phosphate (HPO_4^{2-}) anions concentration. The sulphate (SO_4^{2-}) and hydrogen phosphate (HPO_4^{2-}) anions concentrations in the bark of the *Pinus sylvestris* L. stem were higher at the top than at the butt-end part.

Introduction

During the process of tree growth, mineral salts naturally accumulate in the tree. Water-soluble salts are deposited in the resin ducts and pith rays. In the tracheids, mineral substances accumulate in the primary and secondary walls and are also deposited as needles or prismatic crystals in the spaces of parenchymatous cells, as well as in the middle lamina (Fengel and Wegener 1984). The mineral substances content of wood growing in temperate climates ranges from 0.3 to 1.2%, based on its dry weight.

The relatively low content of mineral substances fulfill an important function in the physiological process of wood tissue formation (Mansilla et al. 1991). The content of these substances in the wood and bark depends on the tree species, its age, the growth habitat, as well as the sampling location on the cross-section and longitudinal of the trunk (Pereira 1982, 1988; Rademacher et al. 1986, 1988; Krutul 1995, 1996; Watmough and Hutchinson 1999; Krutul et al. 2012, 2014, 2018). Data from Denne and Dodd (1980), Pereira (1982, 1988), Fengel and Wegener (1984), Rademacher et al. (1986), Marques and Pereira (1987), Loto and Fakankun (1989) and Adamopoulos et al. (2005) show that in the wood of the same species, the content of mineral substances varies over a wide range. According to Krutul and Sacharczuk (1997) oak sapwood (*Quercus robur* L.) contains from 0.36 to 0.59% mineral substances which is higher than in heartwood (0.14 to 0.36%). In the wood of the 120-year-old oak trunk (*Quercus petraea* Liebl.) mineral substances content in horizontal cross-sections of 1.8 and 5 m are higher than in the butt-end part, for both - sapwood and heartwood. The tree bark has almost ten times higher mineral substances content compared to wood from the trunk. Krutul and Sacharczuk (1997) determined that mineral substances content in the bark of an oak tree (*Quercus robur* L.) varies from 5.1 to 10.1%. This content in the bark is ten times higher than in wood. Significant differences in mineral substances content were stated in *Pinus sylvestris* L., *Quercus petraea* Liebl. and *Quercus robur* L. wood (cca. 100-year-old) between wood from the top section and the butt-end section. Mineral substances content is higher in wood from the top section but is lower in bark from the top section (Krutul 1996, 1998). Krutul and Makowski (2004) reported that mineral substances content in *Quercus petraea* Liebl. wood is 20% higher in sapwood gained at the 1.8 m height and 30% higher in sapwood at the 5 m height in comparison to

heartwood. Mineral substances content in wood and bark is usually determined based on the ash amount obtained from the burning and ashing of a sample.

Extractives in wood are very diverse concerning chemistry and their distribution on the cross-section and longitudinal of the trunk in wood and bark depends on their function. The decrease of extractives content in the direction from the pith to the perimeter takes place on the cross-section apart from the tree habitat (Krutul and Sacharczuk 1997; Krutul 1998; Krutul et al. 2012). Extractives content in the bark is much higher than in wood. According to Krutul et al. (2007), *Quercus petraea* Liebl. bark contains a three times higher amount of extractives than heartwood and six times higher than sapwood. Ohara and Hemingway (1989) noted that the content of substances extracted with an acetone-water (1:1, v/v) mixture equals 10.7% in internal bark, 14.8% in middle bark and 5.5% in outer bark.

Phosphorus (P) is an element with a key role in transfer reactions and energy accumulation and phosphorylation. It is taken up by plants in the form of H_2PO_4^- (dihydrogen phosphate) and HPO_4^{2-} (hydrogen phosphate) anions. It actively incorporates a variety of compounds in its oxidized form to form phosphoric acid (V) esters (Kopcewicz and Lewak 1998). According to Krutul et al. (2015) in the wood of the trunk *Morus alba* L., regardless of the height of the cross-section, a higher content of hydrogen phosphate anions is characterized by the sapwood zone relative to their content in pith adjacent heartwood and heartwood zones. Passialis et al. (2008) reported that phosphorus content in the trunk of *Robinia psuedoacacia* L. in sapwood is higher in relation to juvenile and mature wood, obtained from different habitats. In the wood of the trunk of *Quercus petraea* Liebl. sapwood zone is characterized by three times higher hydrogen phosphate anions content than their content in the heartwood zone. Regardless of the degree of environmental contamination by the nitrogen industry and the height of the cross-sections taken of the stems of *Pinus sylvestris* L., the sapwood zone is characterized by a two times to thirteen times higher hydrogen phosphate anions content relative to their content in pith adjacent heartwood zone (Krutul et al. 2015). The bark is characterized by a nine times lower hydrogen phosphate anion content compared to their content in the sapwood zone from the cross-section at 0.1 m (butt-end) of the trunk, fivefold lower from the cross-section at 0.5 m and 1.1 m and more than threefold lower from the cross-section at 2.2 m. Whereas, in relation to the pith adjacent heartwood zone, the bark is characterized by one and a half to fourteen times higher hydrogen phosphate anion content, and in relation to the heartwood zone from one and a half to two times higher this anion content (Krutul et al. 2015).

Sulphur (S) is the element necessary for proper plant development. Plants take up the sulphur by the roots system from the ground in the form of sulphate (SO_4^{2-}) anions or in small amounts as sulphur dioxide from the atmosphere. It is transported by the xylem and appears in many different compounds. Hu et al. (2013) reported that nitrogen and sulphur influence the enzymes activity in a boreal mixed wood forest in western Canada. According to Krutul et al. (1999), sulphur content in the sapwood of 110-year-old *Pinus sylvestris* L. in the butt-end part equals 220 mg/kg, in sapwood adjacent heartwood – 165 mg/kg and in heartwood – 134 mg/kg. In the stem of *Pinus sylvestris* L. obtained from different environmental pollution, the sulphur content in the sapwood zone is higher than in pith adjacent

heartwood and in heartwood (Krutul et al. 2015). In the bark of the trunk of *Morus alba* L. content of sulphate anions (SO_4^{2-}) varies from 278 to 672 mg/kg. Along the height of the trunk sulphate anions (SO_4^{2-}) content increases from the base of the trunk to a height of 2.2 m and is twice higher in relation to their content in the bark at a height of 0.1 m (Krutul et al. 2015). Sulphur content in the bark from the *Pinus sylvestris* L. in the butt-end stem section is six times higher compared to wood (Krutul et al. 1999).

According to Fengel and Wegener (1984), there is a relationship between the extractives and the mineral substances contents in a wood. Generally, wood characterized by a high extractives content is also characterized by increased mineral substances content. However, no such relationship was found in the works of Krutul (1996) and Krutul et al. (1999) in both pine and oak trunks. In the studies of the mechanical properties of wood, it was found that there is a relationship between the share of latewood on the cross-section and longitudinal in the trunk and changes in mechanical properties. Changes in the width of annual rings on the cross-section and longitudinal in the trunk, on the other hand, play an indirect role. In coniferous species, if the width equals from 2 to 3 mm, the wood has the best mechanical properties. There is little information on this subject in the available literature, therefore the proposed research seems to be interesting and important from a scientific and practical point of view.

The aim of this paper is the determination of the concentration of hydrogen phosphate and sulphate anions on the cross-section and longitudinal of the *Pinus sylvestris* L. stem. Additionally, the relationship between extractives and ash contents, width of annual rings, and share of latewood on the cross-section and longitudinal of *Pinus sylvestris* L. stem were examined.

Materials and methods

Samples for studies were gained from the about 100-year-old stem of *Pinus sylvestris* L. The tree grew in Mazovia - Podlaski forest region and was cut in December. The height of the tree was 25 m, including a crown of 9.2 m, and the length of the trunk to the first branch was 34 m. Wood samples for studies were taken from eight disks, collected at the height of 0.2, 4, 8.5, 14, 19, 21, 22.5 and 23.5 m from the ground, which were harvested so that the spacing between disks was 10 meristems. In each disc, wood was collected from individual zones: sapwood perimeter (SP), middle sapwood (MS), sapwood adjacent heartwood (SAH), heartwood adjacent sapwood (HAS), middle heartwood (MH) and pith adjacent heartwood (PAH). Bark samples were taken from three disks, collected at the height of 0.2, 14 and 23.5 m from the ground.

Table 1
The characteristics of the cross-section and longitudinal of the examined disks

height of cross-section [m]	the pith location	number of annual rings		arrangement of annual increments around the pith	diameter [mm]	distinction of the zone in the disk
		heartwood	sapwood			
0.2	centre	61	40	regular	442	(SP) sapwood perimeter, (MS) middle sapwood, (SH) sapwood adjacent heartwood, (HS) heartwood adjacent sapwood, (MH) middle heartwood, (PH) pith adjacent heartwood
4.0	centre	55	45	regular	400	(SP) sapwood perimeter, (MS) middle sapwood, (SH) sapwood adjacent heartwood, (HS) heartwood adjacent sapwood, (MH) middle heartwood, (PH) pith adjacent heartwood
8.5	centre	49	38	regular	388	(SP) sapwood perimeter, (MS) middle sapwood, (SH) sapwood adjacent heartwood, (HS) heartwood adjacent sapwood, (MH) middle heartwood, (PH) pith adjacent heartwood
14.0	non centre	41	35	not regular	253	(P) sapwood, (SH) sapwood adjacent heartwood, (HS) heartwood adjacent sapwood, (H) heartwood
19.0	non centre	37	34	not regular	235	(S) sapwood, (H) heartwood
21.0	non centre	27	26	not regular	184	(S) sapwood, (H) heartwood
22.5	non centre	17	18	not regular	110	(S) sapwood, (H) heartwood
23.5	centre	-	17	regular	54	(S) sapwood, (H) heartwood

Table 1 shows the characteristics of the cross-section and longitudinal of the examined disks. Wood and bark samples were disintegrated in a laboratory mill and fractioned using sieves. Fractions of wood

samples with dimensions of 1.2 mm to 0.49 mm and below 0.15 mm were taken for analysis of extractives content. The Soxhlet apparatus was used for extractives content determination with the ethanol-benzene mixture (1:1)v/v (Krutul 2002).

The mineral substances content in the form of ash was analyzed on a dusty fraction of wood (fraction below 0.15 mm) in a muffle oven at 600°C (Kačík and Solár 1999).

The high performance liquid chromatography (HPLC) with a conductometric detector was applied to determine the concentration of sulphate (SO_4^{2-}) and hydrogen phosphate (HPO_4^{2-}) anions in wood and bark of *Pinus sylvestris* L. stem according to PN-A-79011-7 (1998). In this analysis fraction of wood and bark below 0.15 mm was used.

Determination of percentages of latewood and width of annual rings was carried out following with PN-55/D-04110 (1955).

Results and discussion

The content of extractives decreased in the direction from the pith adjacent heartwood to the sapwood perimeter zone irrespective of the sample fraction (1.2–0.49 mm and below 0.15 mm) on which the determination was carried out (Fig. 1).

From the data shown in Fig. 1, it can be seen that the extractives content was slightly higher in the samples with a fraction of below 0.15 mm in relation to samples with a fraction of 1.2–0.49 mm.

In both samples with a fraction of 1.2–0.49 mm and below 0.15 mm, the extractives content in pith adjacent heartwood and middle heartwood was about three times higher than in the sapwood perimeter zone at the height of 0.2 m, 4 m and 8.5 m of the stem from the ground surface. Whereas at the height of 14 m and 19 m of the stem, the extractives content in pith adjacent heartwood and middle heartwood zone was from 40–45% higher compared to the sapwood perimeter zone, with only 15% higher at the height of 21 m and 22.5 m.

It should be noted that with the increasing height of the *Pinus sylvestris* L. stem, the differences in extractives content between sapwood perimeter and middle heartwood zones decreased. In the stems of 80- 90- and 160-year-old *Pinus sylvestris* L. extractives content on the cross-section decreased from pith adjacent heartwood to sapwood zone at the butt-end part (Krutul 1998).

According to Krutul et al. (2014), the extractives content in the *Quercus robur* L. trunk on the cross-section increased in the direction from the outer wood to the pith.

Ash content (which constitute metal oxides) on the cross-section of the stem *Pinus sylvestris* L. in pith adjacent heartwood and middle heartwood was higher compared to sapwood perimeter, sapwood adjacent heartwood and heartwood adjacent sapwood regardless of the height of the cross-section of the *Pinus sylvestris* L. stem (Fig. 2).

The ash content in the stem of *Pinus sylvestris* L. at the butt-end part and at the height of 4 and 8,5 m in pith adjacent heartwood and middle heartwood zone was about 30% higher than in sapwood perimeter, and at the height of 14, 19, 21 and 22,5 m was about 40 to 50% higher.

Regardless of tree growth habitat, 80-, 90- and 100-year-old *Pinus sylvestris* L. sapwood perimeter zone at the top part of the stem was characterized by higher mineral substances content compared to sapwood at the middle and butt-end part (Krutul 1998). According to Fengel and Wegener (1984), there is a correlation between the extractives content of wood and its mineral substances content. Wood characterized by a high extractives content is also characterized by increased mineral substances content. From the data shown in Fig. 1 and Fig. 2, it can be concluded that at the heights of 0.2, 4, 8.5 and 19 m of the *Pinus sylvestris* L. stem on the cross-section pith adjacent heartwood was characterized by higher extractives content and higher ash content in relation to sapwood perimeter which is in accordance with the statement of Fengel and Wegener (1984).

Meanwhile, at the heights of 21 and 22.5 m of *Pinus sylvestris* L. stem, the extractives and the ash contents in the middle heartwood zone were higher (20% and 50% respectively) in relation to the sapwood perimeter zone. At the top of the stem, ash content in the middle heartwood zone was about 65% higher compared to their content in the middle heartwood zone at 0.2 m height of the stem, while extractives content was over two times less.

According to Krutul et al. (2014) in the trunk of *Quercus robur* L. extractives content in pith adjacent heartwood was higher in relation to the sapwood zone. In the pith adjacent heartwood zone extractives content at the butt-end was 80%, at the middle part - two times and at the top of the trunk it was 50% higher compared to the sapwood zone. On the contrary mineral substances content was higher in sapwood in relation to the pith adjacent heartwood zone longitudinal of the trunk.

Our results showed that extractives and ash contents in wood on the cross-section and longitudinal of the trunk depended on wood species, age and tree habitat.

Figure 3 shows data on the annual ring width on the cross-section and longitudinal of the *Pinus sylvestris* L. stem.

From the presented data it can be concluded that, regardless of the height of the cross-section of the stem, the pith adjacent heartwood and middle heartwood zones were characterized by higher annual ring width in relation to the sapwood perimeter zone. On the cross-section at the stem height of 0.2 m, 4 m and 8.5 m annual rings width in pith adjacent heartwood was about 65% higher in relation to the sapwood perimeter zone (Fig. 3).

On the cross-section of the stem annual rings width increased regularly from sapwood perimeter to middle heartwood and pith adjacent heartwood zone (Fig. 4).

According to Krutul (1996) at the height of 2, 6 and 10 m from the ground of the stem of about 110-year-old *Pinus sylvestris* L. annual rings width was about three times higher in the pith adjacent heartwood

than in the sapwood perimeter zone.

From the data presented in Figs. 2 and 4, it can be concluded that greater annual ring width in pith adjacent heartwood and middle heartwood zone influenced increased content of ash in relation to the sapwood perimeter zone.

Share of latewood on the cross-section in annual rings of the *Pinus sylvestris* L. stem showed that sapwood perimeter zone was characterized from 40% to about three times higher share of latewood in relation to pith adjacent heartwood and middle heartwood zone (Fig. 5). In longitudinal of the stem share of latewood in annual rings was similar. The greatest differences in the share of latewood were from pith adjacent heartwood and middle heartwood at heights of 4 m, and 8.5 m and they amounted 14.8 and 14.5% respectively. At the height of 0.2 m, 14, 19, 21 and 22.5 - from 18.8 to 21.4%.

From the data shown in Fig. 1 and Fig. 5, it can be concluded that the greater share of latewood in annual rings, the lower the extractives content. The sapwood perimeter zone of the *Pinus sylvestris* L. stem was characterized by a higher share of latewood in relation to pith adjacent heartwood and middle heartwood zone and extractives content was between three and 10 times lower than middle heartwood zone.

Depending on the share of latewood in the investigated zones of the wood, the ash content on the cross-section and longitudinal of the *Pinus sylvestris* L. stem was similar to extractives content (Fig. 1 and Fig. 2).

On the cross-section at the height of the stem 0.2 m, 4 m and 8.5 m share of latewood was 30% lower in pith adjacent heartwood compared to the sapwood perimeter zone. At the height of the stem 14 m, 19 m, 21 m and 22.5 m from the ground was about 50% lower in middle heartwood in relation to the sapwood perimeter zone (Fig. 5).

Ash is composed of metals oxides, while non-metals oxides are gases oxides and therefore phosphorus and sulphur are not included in total content of ash. Both phosphorus and sulphur are essential elements for proper plant development and are classified as macroelements.

It can be seen from the data presented in Fig. 6 that the hydrogen phosphate anions concentration on the cross-section of *Pinus sylvestris* L. stem from sapwood perimeter was about 8 times higher in relation to pith adjacent heartwood at the height of the stem 0.2 m, 4 m and 8.5 m from the ground.

At the height of the stem 14 m, 19 m, 21 m and 22 m from the ground hydrogen phosphate anions concentration was from two to six times higher in sapwood perimeter in comparison to the middle heartwood zone. According to Krutul et al. (2014) apart from environmental pollution, sapwood is compatible with heartwood.

These results are compatible with the data of Krutul et al. (1999) which showed the same relationship in 110-year-old *Pinus sylvestris* L.

According to Passialis et al. (2008) phosphorus content in *Robinia pseudoacacia* L. in sapwood was sevenfold higher in comparison to juvenile and mature wood obtained from different habitats (Greece, Bulgaria and Hungary).

Regardless of the height of the cross-section of the trunk of *Morus alba* L., a higher content of hydrogen phosphate anions (HPO_4^{2-}) was characterized in the sapwood zone in relation to their content in pith adjacent heartwood and heartwood zone (Krutul et al. 2015).

The data presented in Fig. 1, Fig. 2 and Fig. 6 shows that the distribution of hydrogen phosphate anions (HPO_4^{2-}) on the cross-section of the *Pinus sylvestris* L. stem was different from the distribution of extractives and mineral substances.

The sapwood perimeter zone of the stem was characterized by lower annual rings width and a higher share of latewood in comparison to pith adjacent heartwood and middle heartwood. The hydrogen phosphate anions concentration in the sapwood perimeter zone was several times higher in comparison to pith adjacent heartwood and middle heartwood (Fig. 4 and Fig. 6).

The hydrogen phosphate anions concentration in the bark of the *Pinus sylvestris* L. stem equaled 299 mg/kg at the butt-end (0.2 m), 358 mg/kg at a height of 14 m and 319 mg/kg at the top part (23.5 m) (Fig. 6).

In the bark of the pine stem hydrogen phosphate anions concentration at the top part and 14 m height in comparison to the butt-end was 16% and 21% higher, respectively.

The hydrogen phosphate anions concentration in the bark of the trunk of *Morus alba* L. varied from 82 to 130 mg/kg. On the cross-section at the height of 0.1 and 0.5 m from the ground the hydrogen phosphate anions concentration was from 40–60% lower in comparison to heights of 1.1 and 2.2 m.

The bark had nine times lower hydrogen phosphate anions concentration in comparison to their content in the sapwood perimeter zone from the cross-section at the height of 0.1 m and five times lower from the cross-section at the heights of 0.5 and 1.1 m and more than three times lower from the cross-section at the height of 2.2 m from the ground.

Whereas hydrogen phosphate anions concentration in the trunk of *Quercus petraea* Liebl. at the height of 5 m was eight times less in comparison to the sapwood zone, but one and a half times higher than the heartwood zone (Krutul et al. 2007).

Bark from the stem of *Pinus sylvestris* L. obtained from environments with varying degrees of contamination was characterized by one and a half to ten times lower hydrogen phosphate anions concentration relative to their content in sapwood zone, but one and a half to four times higher relative to their content in pith adjacent heartwood (Krutul et al. 2015).

The data presented in Fig. 7 shows that regardless of the height of the cross-section of the *Pinus sylvestris* L. stem, the sapwood perimeter zone had a higher concentration of sulphate anions (SO_4^{2-}) in comparison to the concentration in pith adjacent heartwood and middle heartwood zone.

In the bark of the *Quercus petraea* Liebl. trunk at the height of 5 m from the ground equaled 647 mg/kg. In the bark of the *Morus alba* L. trunk sulphate anions (SO_4^{2-}) concentration was from 278 mg/kg to 672 mg/kg. In longitudinal of the trunk sulphate anions concentration increased from the butt-end to the height of 2.2 m (Krutul et al. 2015).

Based on the data presented in Figs. 1, 2 and 7 it can be stated that sulphate anions distribution on the cross-section of the *Pinus sylvestris* L. stem was different than extractives and ash distribution.

Sulphate anions distribution on the cross-section was similar to hydrogen phosphates anions (HPO_4^{2-}) distribution (Figs. 6 and 7). Sulphate anions distribution on the cross-section and longitudinal of the *Pinus sylvestris* L. stem depended on the annual rings width and the share of latewood in annual rings (Figs. 4 and 7).

Conclusions

On the base of the results following conclusions can be drawn:

- Extractives content on the cross-section of the *Pinus sylvestris* L. stem regardless of the fraction (1.2–0.49 mm and below 0.15 mm) of analyzed samples increased in the direction from sapwood perimeter to middle heartwood and pith adjacent heartwood zone.
- Annual rings width was higher in pith adjacent heartwood and middle heartwood in relation to sapwood perimeter zone and influenced a higher ash content in these zones relation to sapwood perimeter zone.
- The sapwood perimeter zone was characterized from 40% to three times higher share of latewood on the cross-section in annual rings of the *Pinus sylvestris* L. stem compared to pith adjacent heartwood and middle heartwood zone.
- The greater the share of latewood in annuals rings the lower extractives and ash contents.
- Hydrogen phosphate anions concentration in sapwood perimeter zone was several times higher compared to pith adjacent heartwood and middle heartwood zone and the distribution of this anion on the cross-section and longitudinal of the stem was similar with the share of latewood in annual rings.
- Sulphate anions (SO_4^{2-}) distribution on the cross-section of the *Pinus sylvestris* L. stem was different from the extractives and ash distribution, but it is similar to hydrogen phosphate anions (HPO_4^{2-}) distribution.
- Sulphate anions (SO_4^{2-}) concentration on the cross-section of the stem depended on the annual rings width and the share of latewood in annual rings.

Declarations

Conflict of interest

The article does not contain any conflicts of interests.

Author Contribution

Conceptualization: DK; Material acquisition: DK; Methodology: DK, AA and AR; Formal analysis and researches: all authors; Writing – original draft preparation: DK, AA and MM; Writing – review and editing: all authors. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

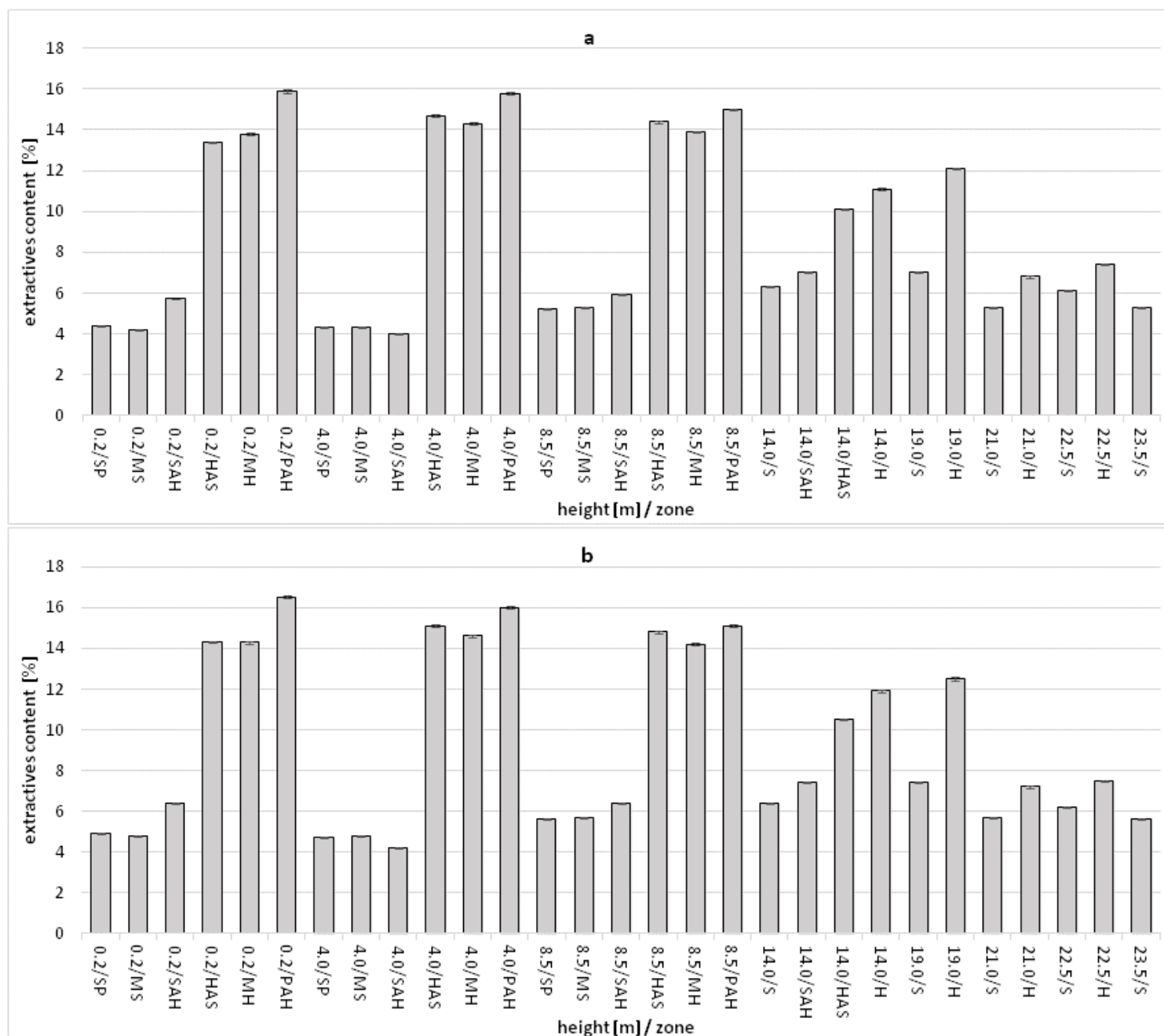


Figure 1

Extractives content in wood on cross-section and longitudinal of the *Pinus sylvestris* L. stem (a - fraction 1.2-0.49 mm, b - fraction below 0.15 mm)

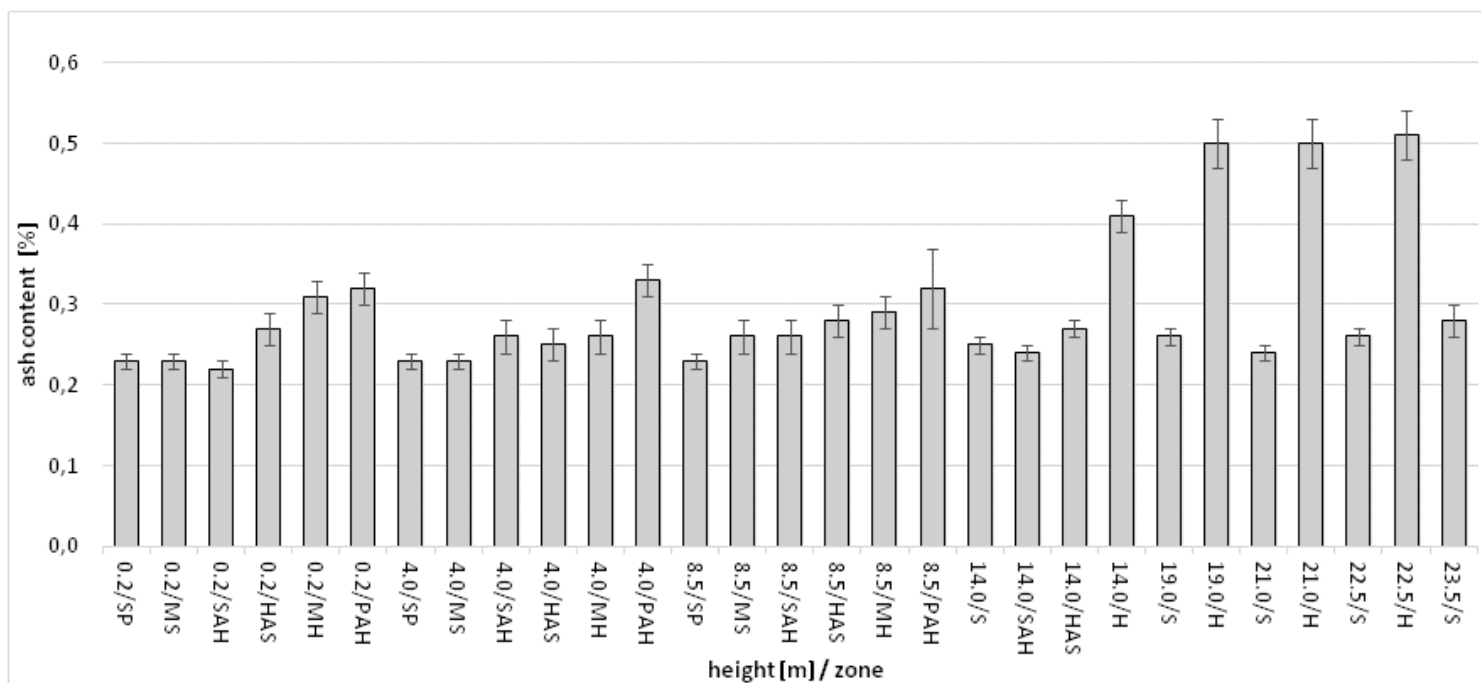


Figure 2

Ash content in wood on cross-section and longitudinal of the *Pinus sylvestris* L. stem

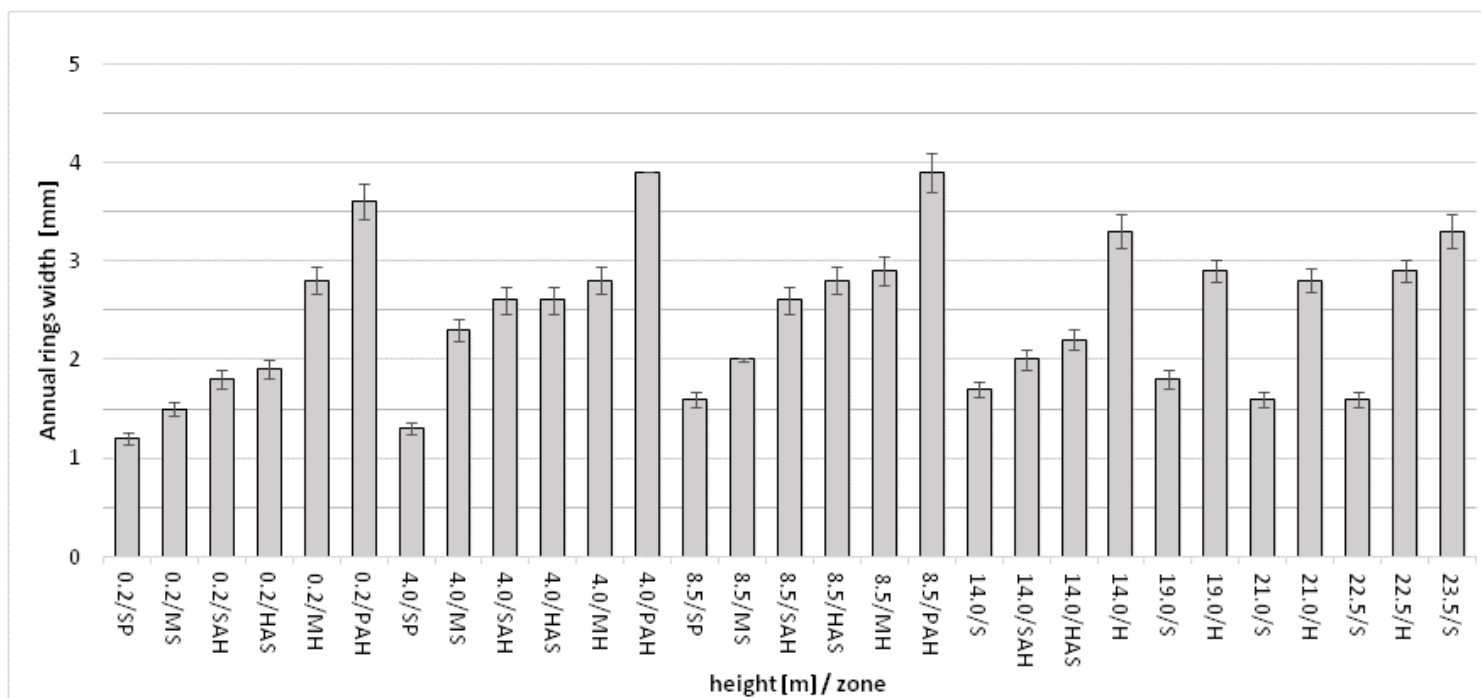


Figure 3

Annual rings width on cross-section and longitudinal of the *Pinus sylvestris* L. stem

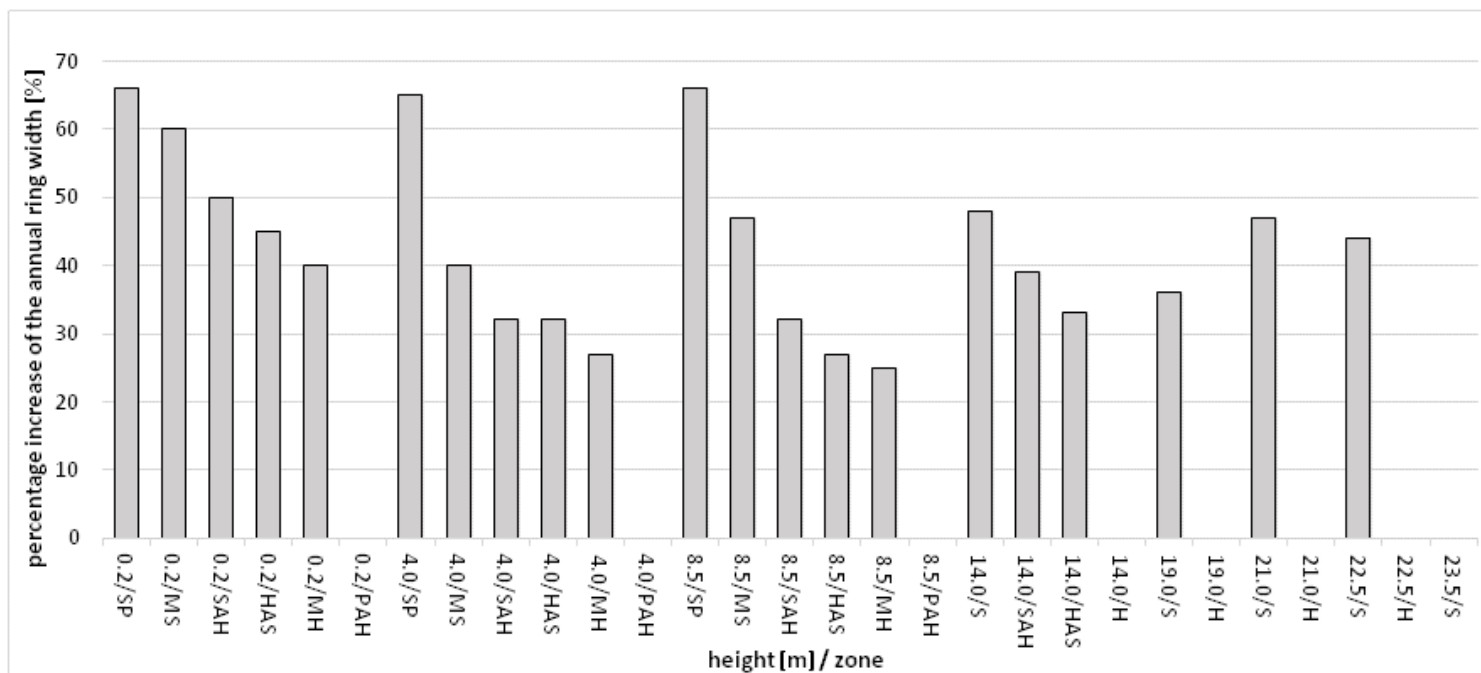


Figure 4

Percentage increase of the annual ring width from sapwood to pith adjacent heartwood and middle heartwood zone on the cross-section and longitudinal of the *Pinus sylvestris* L. stem

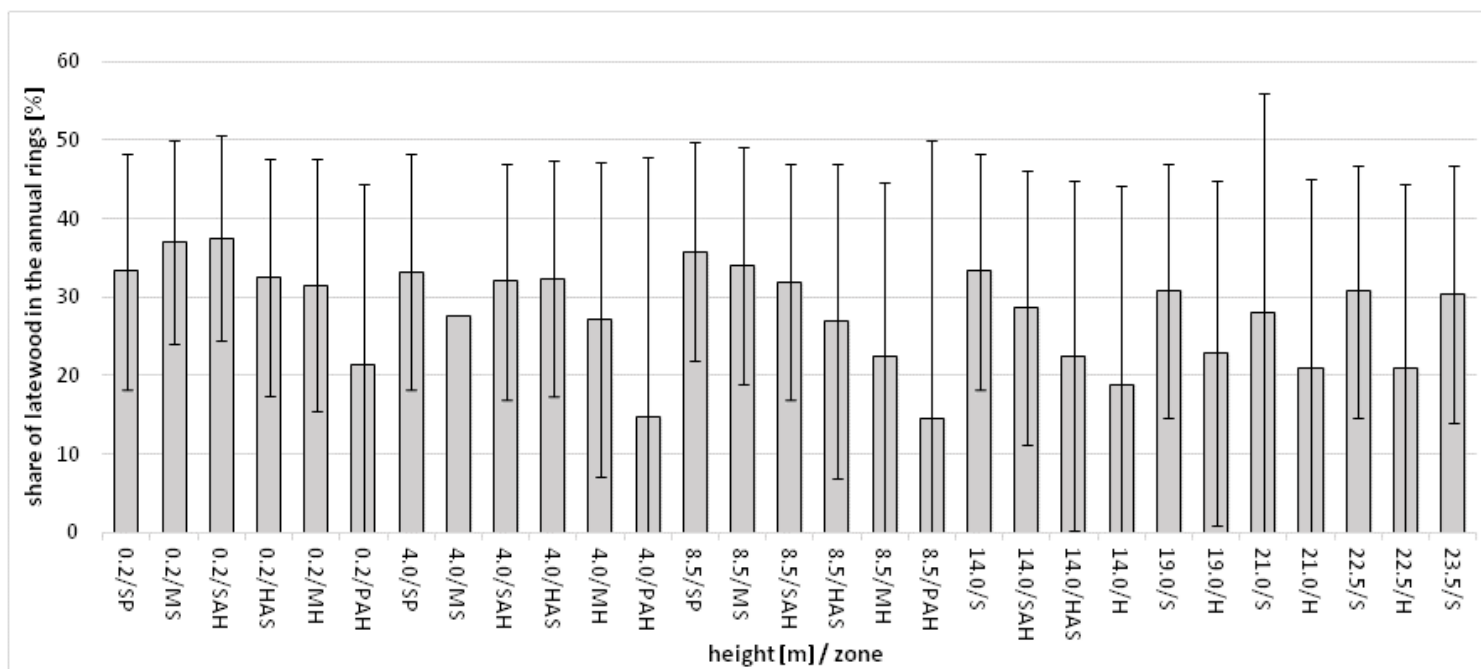


Figure 5

Share of latewood in the annual rings on cross-section and longitudinal of the *Pinus sylvestris* L. stem

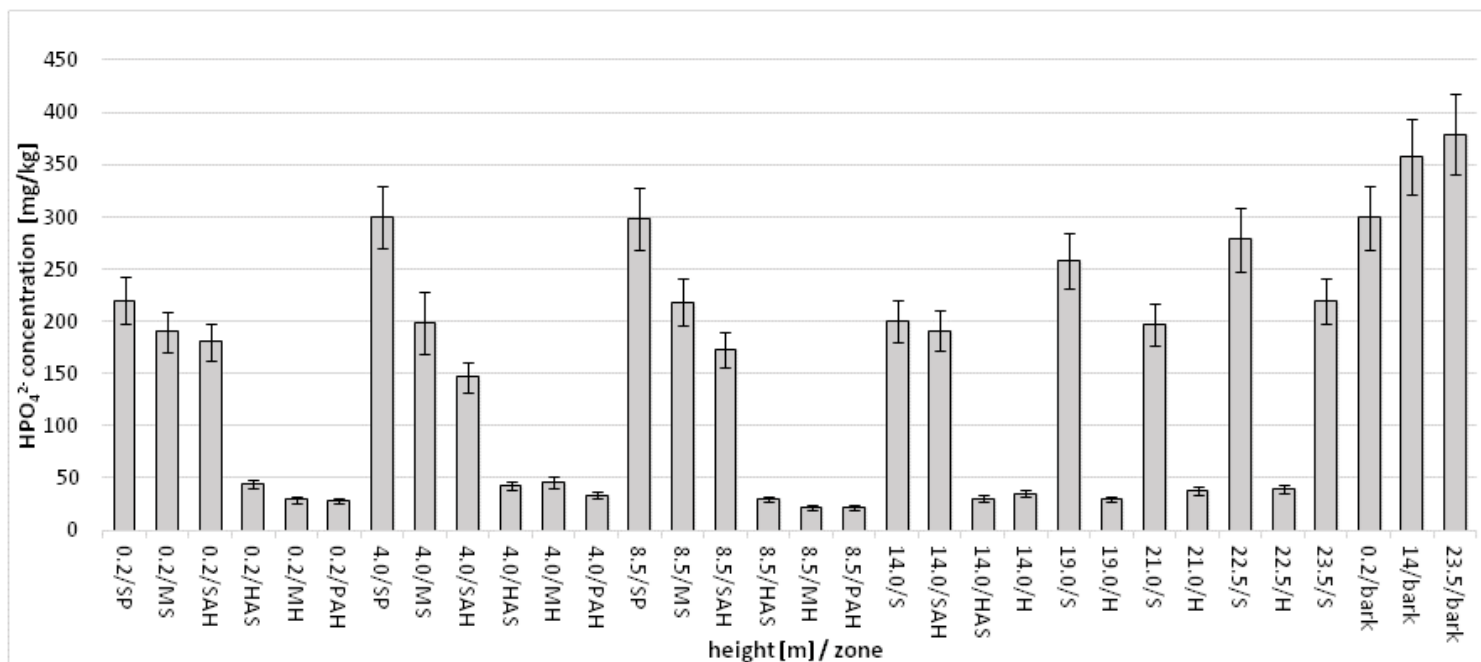


Figure 6

Hydrogen phosphate anions (HPO₄²⁻) concentration in examined wood zones and bark of the *Pinus sylvestris* L. stem

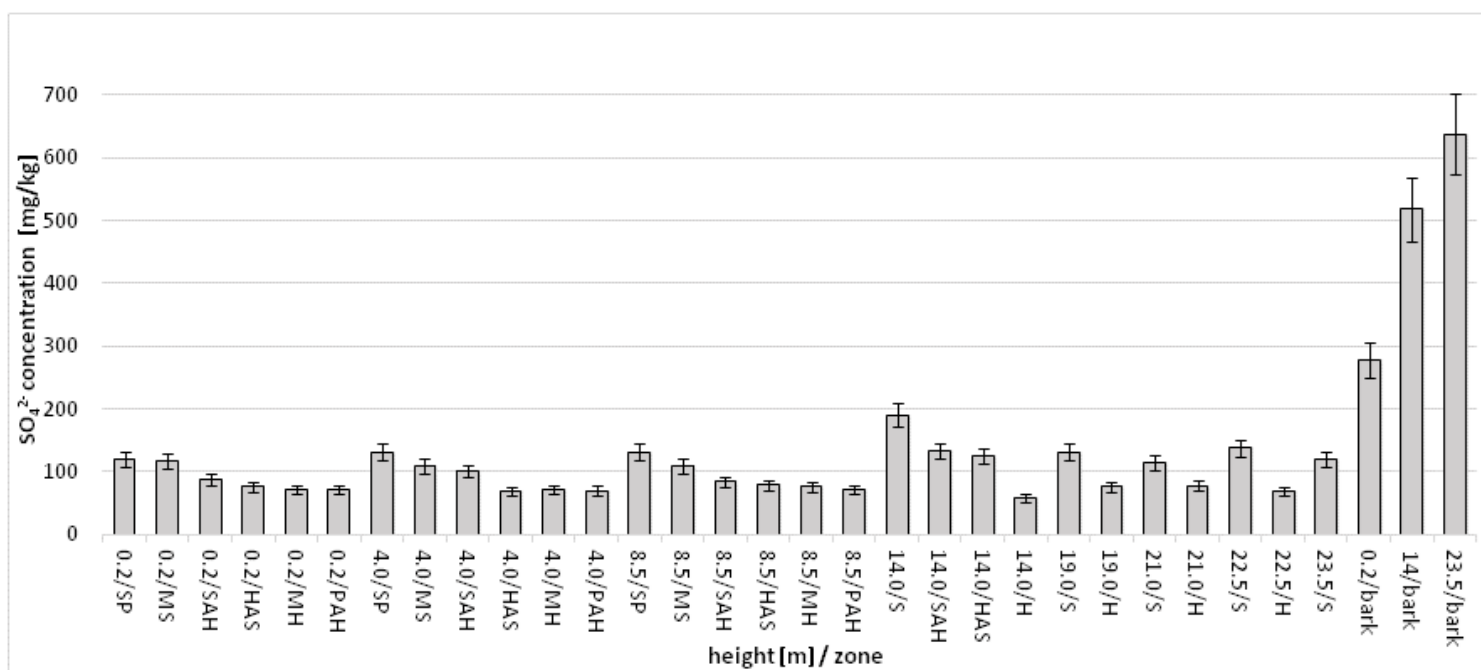


Figure 7

Sulphate anions (SO₄²⁻) concentration in examined wood zone and bark of the *Pinus sylvestris* L. stem