Article citation info:
Michalec K., Wąsik R., Gach M.B., Kulak D., Stańczykiewicz A., Mateusiak Ł. 2026. Development of Latent Defects in Pine and Spruce Timber Stored for a Long Time in a Landing Yards. *Drewno. Prace naukowe. Doniesienia. Komunikaty* 69 (218): 00084. https://doi.org/10.53502/wood-210484

Drewno. Prace naukowe. Doniesienia. Komunikaty
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Journal website: https://drewno-wood.pl

Development of Latent Defects in Pine and Spruce Timber Stored for a Long Time in a Landing Yards

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Article info
Received: 23 May 2025
Accepted: 9 September 2025
Published: 20 March 2026

Keywords
blue stain
hard rot
soft rot
medium-sized firewood
biomass

Deadwood landings were established in three locations in Poland – two for the storage of pine timber, and one for spruce timber. Three measuring baskets were placed on each landing yard. In each basket, rollers were arranged in three test layers. In each test layer, 7 rollers were arranged. Each test roller was cut in the middle of its length, and a disc was taken from its inner part for further analysis. Each disc was photographed. Photographs obtained during successive trials were analyzed with the Multi Scan program. During the 54 months of research, 12 measurements were performed. On the faces of pine and spruce rollers, an increase in the area occupied by blue stain was initially observed, and then the area of blue stain began to decrease. A similar trend was also observed in the case of hard rot. In the case of soft rot, a large variability was observed in the areas in the subsequent months of the study. However, in the final stage of the study, an increase in the area of the faces occupied by soft rot was observed. As a result of the research it was found, it can be stated that the process of pine wood decomposition occurs, but it is very slow. In the case of spruce wood, the decomposition process is more intense and is particularly visible after 18 months of storage.

DOI: 10.53502/wood-210484

Introduction

In recent years, we have been observing various disaster events in forests, as well as prolonged periods of drought and lowering of groundwater levels, which result in significant amounts of deadwood, even in pine stands, previously considered relatively resistant to this phenomenon. More and more often, one of the reasons for the appearance of significant amounts of deadwood is fires and the subsequent insect infestations (Capecki, 1993; Piszczek and Kuc, 2013; Bruchwald et al., 2019; Barmpoutis et al., 2020; Kastridis et al., 2022). Annually, this is on average about 15% of wood harvested in the State Forests in Poland (Statistics Poland, 2024). Such wood often has to be stored in landing yards for a longer period of time due to the lower interest in this type of raw material from wood processing plants. This wood is also of poor quality and is intended for heating purposes. The cause of this phenomenon is the appearance of a blue stain, and then rot. The occurrence of these defects significantly limits the use of the raw material. In Polish standards, hard rot is not allowed

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in rades S1 (mining timber, long logs), S2 (pulpwood), and S3 (pole). In turn, soft rot is only allowed in group S4 (fuel) and only in the size of up to 50% of the surface of the ends. If the surface of soft rot is larger, such wood is not suitable for use (Kimbar, 2011; Technical Conditions, 2019a; 2019b). In terms of structure and chemical composition, wood is a heterogeneous raw material, and the issue of its changes and decomposition over time can be described separately, distinguishing, among others, bark, phloem, cambium, sapwood, or heartwood (Kokociński, 2005). These elements can be considered as chemical or anatomical components. Differences between early and late wood and in the structure of vessels and tracheids affect the ability of wood-decomposing organisms to take over. Wood decomposition is influenced by the share of cellulose, hemicelluloses, and lignin (Harmon et al., 1986). The presence of gums, resins, and tannins in wood can also hinder the development of wood-destroying organisms, acting toxically on fungi, bacteria, and insects. Resins and gums also create a mechanical barrier for wood-inhabiting organisms (Krajewski and Witomski, 2016). The rate of wood decomposition is influenced not only by its components but also by other factors such as: climate, microrelief, exposure, altitude, slope, type of surface, fertility and humidity of the site, stand density and height, density, tree position, contact area of wood with the ground, bark loss and drying of wood, fungal infections, cause of death and the occurrence of wood-decomposing organisms (Naesset, 1999; Zhou et al., 2007; Rock et al. 2008).

To the authors' knowledge, no studies have yet been conducted on changes occurring on the faces of deadwood stored in real (not simulated) forest landing yard conditions. This paper focuses on the changes occurring in wood as a result of long periods of storage of wood arranged in stacks without additional protection against depreciation, and the aim is to analyse the changes in the extent of discolouration and rot occurring on the inner faces of pine and spruce rollers stored for a long time in a landing yard. It should be emphasized that the studies were conducted in landing yards where large quantities (several hundred cubic meters) of deadwood were accumulated and remained in the landing yard throughout the experiment, making the obtained results unique, at least on a European scale.

Materials and methods

Deadwood yards were established in three locations in central and southern Poland. Pinewood (PI) was stored in landing yards in the Garwolin Forest District (GPS – 51°55'45"N 21°35'18"E) and Spała Forest District (GPS – 51°34'17"N 20°14'11" E) located in central Poland. Sprucewood (SP) was stored in a landing yard in the Lądek Zdrój Forest District (GPS – 50°18'28.4"N 16°52'41.5" E) located in southwestern Poland. Approximately 600 m^3 of deadwood (Michalec et al., 2024a; 2024b) was stored in each landing yard, which had separated into the stands in the year preceding the start of the experiment.

During the stacking of the piles, measuring points were set up, hereinafter referred to as measuring baskets. These were rectangular structures made of galvanized steel pipes, 1.2 m wide, 2.5 m deep, and with a height of the pile. In each pile, the measuring baskets were placed no closer than 50 m from each other in order to create the same external conditions affecting the tested wood. Due to the assumed purpose of the research, the wood in the measuring baskets and the wood adjacent to the baskets were not used for the duration of the experiment (54 months). The internal space of the measuring basket was filled with straight wood, without visible curves, which facilitated measurements and reduced the risk of making an error. Three measuring baskets with deadwood from nearby stands were placed on each storage site.

In each measuring basket, permanently marked "test rollers" were arranged in three layers, i.e., the second from the bottom (hereinafter referred to as the bottom (1)), in the middle of the stack height (the so-called middle (2)), and the second from the top (the so-called top (3)). In each layer, 7 rollers were arranged, representing the range of roller diameters in stacks. A total of 21 test rollers were arranged in each basket (Fig. 1). After the piles were created and the baskets were filled with wood, the first measurements were taken at the landing yard, which constituted the so-called zero test (month 0 in the figures and tables).

During the measurements in test 0, each sample roller was permanently marked with an identification code, then cut in half, and a disc was cut off from the inner face for further analysis. Then, to limit the influence of the environment inside the piles, the inner faces of the rollers were covered with black foil and placed in a measuring basket, in an appropriate layer, so that the two inner faces formed after taking the discs were in contact with each other. During the subsequent measurements, 1 disc was taken for analysis each time from the same half of the roller, previously cutting off a layer of wood about 2-3 cm thick in order to remove changes in the wood discoloration caused by infection with blue stain fungi on the face of the roller. Each cut disc was marked with an appropriate number (Fig. 2).

Then a photo of the face of each disc was taken in order to calculate its area and the area of blue stain, hard, and soft rot. The photos were taken with a CANON EOS 760D camera, in the same conditions: distance 1 meter, same angle, resolution 72 dpi. During the photographing, a template with a grid of squares with a side

Fig. 1. Location of the test rollers in the measuring baskets

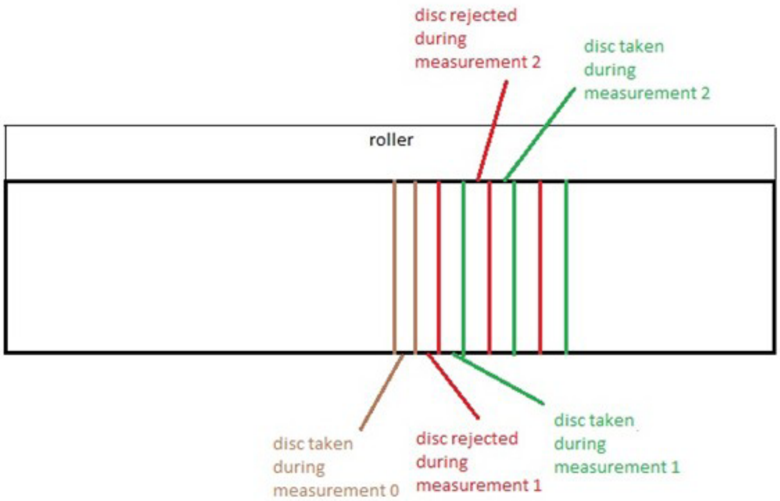

Fig. 2. Diagram of collecting discs for measurements

of 1 cm was applied to each disc in order to calibrate the Multi Scan program, which was used for graphical image analysis (MultiScan v.18.03 Program, Computer Scanning System, Poland). This program allows for determining the size of the discoloration area based on the color difference. The procedure can be performed in automatic or manual mode. To obtain maximum measurement accuracy in our analyses, the shape and area of discoloration and wood defects were determined manually. The measurements made it possible to calculate the area of blue stain and the area of rot (hard and soft) in relation to the area of the entire front of each disc. All the measurement works presented above were carried out at the landing yards 12 times, i.e., immediately after forming the piles and filling the measuring baskets with wood (sample 0), and then at intervals of 6, 9, 12, 15, 18, 24, 30, 36, 42, 48, and 54 months after the zero sample.

Due to the fact that after applying the Shapiro-Wilk test, the null hypothesis of the normality of the empirical data distributions was rejected, the Kruskal-Wallis test and the post-hoc multiple comparison test were used to statistically analyze the significance of differences. Statistica 13.3 (Kot et al., 2007; Tibco Software Inc., 2017) was used for statistical analyses – the significance level of $p = 0.05$ was adopted. Due to the large number of comparisons, the next section, "Results and discussion," includes statistical analyses of data collected after 54 months, including statistical differences between individual layers, as well as between the initial measurement (0) and the final measurement, after 54 months.

Results and discussion

During the entire period of the study, a total of 2268 discs were collected. Figure 3 shows the changes in the blue stain surface over time, taking into account the three layers in which the test rollers were stored. In the case of pine wood, the percentage of blue stain found on the faces of the test rollers was several times higher compared to the percentage of blue stain on

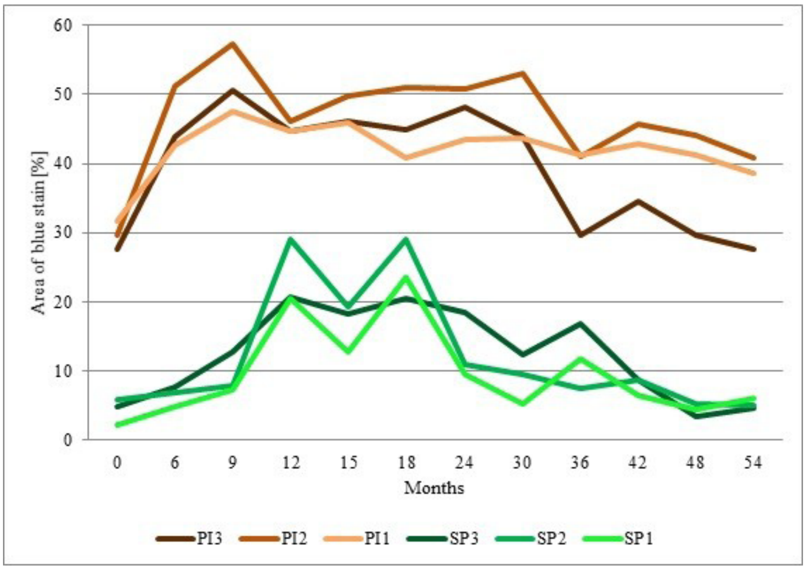

Fig. 3. Changes in the blue stain area in pine and spruce wood depending on the position in the layer (PI – pine, SP – spruce; 1, 2, 3 – layers)

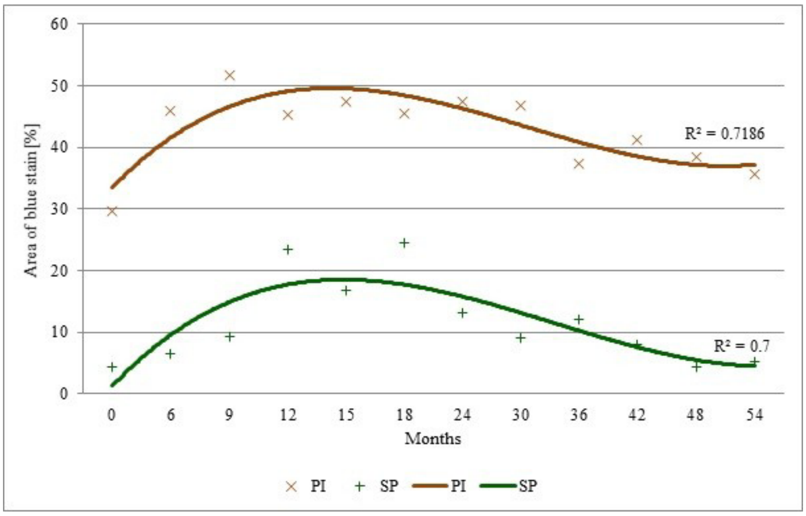

Fig. 4. Change of the blue stain area in pine and spruce wood on all test rollers combined

spruce wood. The difference between the types of wood remained at a very similar level throughout the entire period of the experiment (Fig. 4).

Analyzing the share of blue stain surface on the fronts of pine rollers after 6 months of storage, an increase in the surface of the fronts occupied by blue stain was observed in all layers (Fig. 3 and 4, Table 1). This phenomenon occurred in the spring and summer period, when conditions for the growth of fungi are most favorable. After this period, a gradual decrease in the blue stain surface was observed. Similar trends were observed on spruce wood as on pine wood, with the development of blue stain occurring slowly until the 9th month. Then, a rapid increase in the surface occupied by blue stain was observed. This was particularly visible in the lower and middle layers (SP1 and SP2). The high level of fronts occupied by blue stain was maintained until the 18th month. After that time, the blue stain on the surface began to gradually decrease. However, the Kruskal-Wallis test did not show any significant differences in the blue stain area between individual layers after 54 months on both pine and spruce discs (PI: $H=5.4957$, $p=0.0641$; SP: $H=0.4915681$, $p=0.7821$, respectively) (Fig. 3), nor between the initial measurement (sample 0) and the last one – after 54 months (Fig. 4).

The reduction of the blue stain area was caused in the discussed cases by the development of hard rot, and thus the replacement of blue stain by rot. The fluctuations in the size of the blue stain area observed during this study are explained by Krajewski and Witomski (2016). They stated that blue stain may appear on wood immediately after it is cut. However, if the wood dries out, a hidden blue stain occurs, and the discoloration may be difficult to

Table 1. Descriptive statistics of the blue stain percentage on the test rollers' faces

Months	0	6	9	12	15	18	24	30	36	42	48	54
Pine (PI)												
Average [%]	29.63	45.93	51.77	45.21	47.29	45.56	47.42	46.84	37.31	41.08	38.29	35.61
Median [%]	29.98	45.78	51.14	44.53	49.89	47.66	47.67	47.56	33.47	40.21	38.58	31.12
Min [%]	0.00	2.12	1.52	0.00	2.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max [%]	77.67	88.85	89.33	100.00	88.05	98.77	90.36	90.29	94.40	97.14	96.39	95.06
SD [%]	23.41	21.49	21.07	27.51	22.08	24.58	23.18	23.21	30.50	29.16	29.20	28.36
CV [%]	79.00	46.78	40.70	60.86	46.69	53.96	48.87	49.56	81.74	70.98	76.27	79.63
Spruce (SP)												
Average [%]	4.28	6.45	9.26	23.32	16.77	24.36	13.01	9.08	11.99	7.97	4.29	5.28
Median [%]	0.00	1.31	3.90	19.28	11.96	18.36	6.46	3.75	0.00	0.00	0.00	0.00
Min [%]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max [%]	44.50	49.17	53.91	79.90	100.83	89.78	62.75	49.89	100.00	49.33	39.01	38.79
SD [%]	9.01	10.11	12.25	19.76	19.97	24.83	15.61	12.11	19.07	13.83	9.22	8.55
CV [%]	210.36	156.88	132.34	84.75	119.09	101.92	119.95	133.32	159.03	173.55	215.19	161.75

notice. However, after the occurrence of favorable conditions, e.g., after the wood becomes damp, the discoloration may become visible again.

Other authors (Szewczyk et al. 2020) found that the development of blue stain was influenced not only by the storage period but also by the air temperature around the pile. Temperatures above 16°C had a particularly positive effect on the development of blue stain, while when the temperature dropped below 12°C, the development of blue stain slowed down. The authors also showed that on wood harvested in summer, blue stain developed faster than on wood harvested in spring. Unfortunately, these authors (Szewczyk et al., 2020) continued the study for only 12 weeks and showed a constant increase in the blue stain area. Our study was conducted much longer, and the intervals between measurements were much longer. Therefore, an increase in the blue stain area was observed at the beginning, and later this area decreased. Millers et al. (2017) also showed that temperature, humidity, and storage period affect the development of blue stain. They also showed that the rate of blue stain development is influenced by the technical level of timber harvesting (using a chainsaw – motor-manual or a harvester – fully mechanized [Erler et al. 2024]), the diameter of the rollers, the method of fungal spore dispersal, the location of the rollers in the pile, and the location from the front. The tree species may also have an impact on the development of blue stain. Beal et al. (2010) found that pine wood showed the largest blue stain area (about 70% of the surface), and spruce wood the smallest (about 10%). The authors explain this by the fact that the moisture content of pine wood decreased very slowly and at the end of the 4-month experiment was higher than in the case of spruce wood. Our studies also showed smaller blue stain areas on spruce rollers than on pine rollers (Fig. 3 and 4). Other studies by the authors (Michalec et al., 2024b) conducted on the same test rollers but on the outer faces, which were intact throughout the study period, showed that the blue stain disappeared completely on the pine faces after 12 months, while on the spruce wood after 9 months. This was caused by severe drying of the wood, the leaching of pigment from the mycelium hyphae by atmospheric precipitation, and the development of hard rot, which began to replace the blue stain.

In the case of rots (hard and soft), a different situation was observed. In general, a higher share of these defects was noted in spruce wood, almost throughout the entire period of the experiment. The differences found were not as noticeable as in the case of blue stain (Fig. 5–8).

In pine wood landing yards, hard rot developed gradually in all layers, reaching the maximum surface area after 18 months (Fig. 5 and 6, Table 2). After this time, the degree of frontal invasion by hard rot gradually decreased. The largest areas of hard rot were found in the upper layers (PI3). In the lower layers (PI1

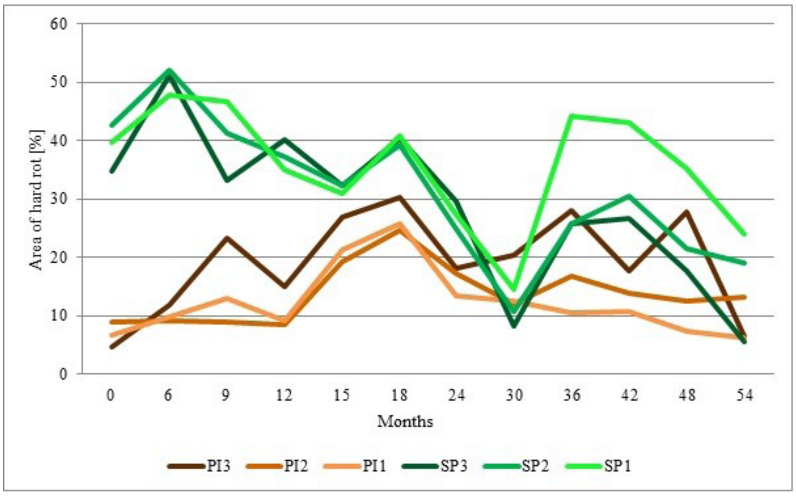

Fig. 5. Changes in the area of hard rot in pine and spruce wood depending on the position in the layer (PI – pine, SP – spruce; 1, 2, 3 – layers)

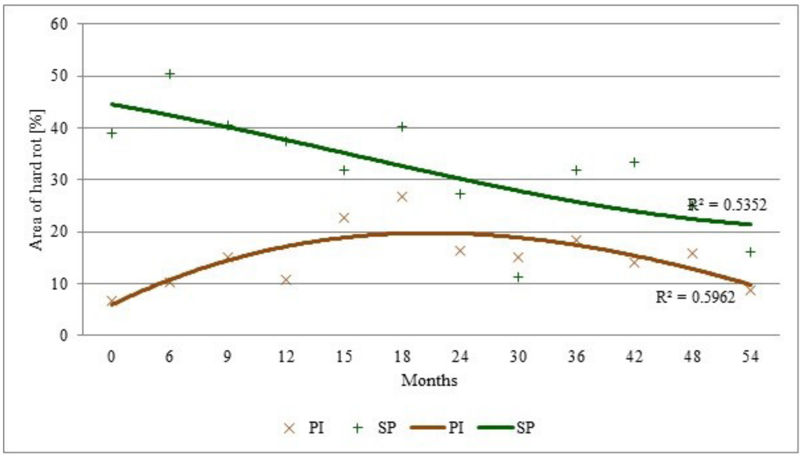

Fig. 6. Change of hard rot area in pine and spruce wood on all test rollers combined

and PI2), the invasion of frontal invasion by rot was smaller. Fluctuations in the area of frontal invasion by rot resulted from the fact that a new disc was taken for measurement each time, while the gradual decrease in the area of rot resulted from the transition of hard rot to soft rot, which did not change the area of rot, but its type changed. In the case of spruce wood, already at the stage of establishing the experiment, some of the fronts showed almost complete control by hard rot (Table 2), and the culmination of the control of the fronts by rot occurred much earlier than in pine wood, because after 6 months of storage (Fig. 5 and 6). After this time, the area of hard rot began to gradually decrease, which resulted from the gradual development of soft rot.

However, after 54 months of testing on spruce wood (similarly to pine), the presence of rollers was found whose surfaces were not affected by rot, as well as rollers whose surfaces were completely (100%) affected by this rot (Table 2). The Kruskal-Wallis test did not show any significant differences in the area of hard rot on the faces of pine rollers between individual layers after 54 months ($H = 6.564175$, $p = 0.0376$) (Fig. 4). However, the statistical test showed significant differences in the area of hard rot on the faces of spruce rollers between individual layers after 54 months ($H = 9.642189$ $p = 0.0081$). However, deepening this analysis with a post-hoc test, it was found that only the faces from layers 1 (lower) and 3 (upper) differ significantly. No significant differences were found in the area of hard rot on the faces of pine rollers between the initial and final measurement (after 54 months) (Fig. 6). However, significant differences were found on the faces of spruce rollers ($p=0.0004$).

The average values for soft rot on pine discs, in total at two landing yards in the Garwolin and Spała Forest Districts, ranged from 1% to 20% (Fig. 7 and 8, Table 3), with frequent fluctuations. However, in the final stage of the study, an increase in the area of fronts affected by soft rot was observed. This was particularly visible in the upper layer (PI3). After 54 months of pine wood storage, the average area

Table 2. Descriptive statistics of the percentage of hard rot on the test rollers' faces

Months	0	6	9	12	15	18	24	30	36	42	48	54
							Pine (PI)					
Average [%]	6.69	10.30	15.06	10.82	22.57	26.82	16.26	15.01	18.42	14.05	15.84	8.60
Median [%]	2.87	6.00	10.92	8.86	19.71	25.24	11.99	13.30	0.00	0.00	0.00	0.00
Min [%]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max [%]	38.24	58.37	67.15	40.42	91.36	65.07	61.12	51.84	89.66	89.59	89.99	81.04
SD [%]	8.78	12.94	15.37	9.85	16.38	14.82	13.14	12.65	27.58	20.73	21.85	16.35
CV [%]	131.20	125.64	102.06	91.02	72.58	55.27	80.81	84.26	149.72	147.53	137.89	190.26
							Spruce (SP)					
Average [%]	38.99	50.30	40.38	37.44	31.85	40.09	27.23	11.12	31.95	33.39	24.88	16.15
Median [%]	35.76	55.56	43.38	39.08	30.15	41.77	21.81	4.27	23.09	23.61	23.24	9.83
Min [%]	0.00	0.00	0.00	0.00	1.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max [%]	95.63	99.98	99.06	85.25	77.09	80.24	84.21	67.06	100.00	100.00	100.00	89.71
SD [%]	28.53	32.95	33.15	17.73	16.50	20.55	21.09	15.22	32.94	31.31	22.52	22.40
CV [%]	73.17	65.52	82.08	47.36	51.81	51.26	77.43	136.80	103.08	93.76	90.49	138.67

of soft rot on rollers in this layer was about 20%, and both rollers without soft rot on their fronts and rollers with fronts almost completely (99%) affected by this rot were observed (Table 3).

The average values for soft rot on spruce discs ranged from 5% to 40% (Fig. 8, Table 3), and in the upper layer (SP3), even up to 50% (Fig. 7). The fluctuations in the degree of frontal invasion by soft rot were significantly greater than in pine wood. Here too (similarly to pine), in the final stage, an increase in the area of frontal invasion by soft rot was observed, especially visible in the upper layer (SP3). After 54 months of the study, the average area of soft rot on the faces of rollers in the lower layer (SP1) and the middle layer (SP2) was about 20%, while in the upper layer (SP3) it was over 40%, and (similarly to pine) both rollers without soft rot on their faces and rollers with their faces completely (100%) affected by this rot were found.

The Kruskal-Wallis test showed significant differences in the soft rot area on both pine and spruce rollers faces between individual layers after 54 months (PI: H=30.30688, p=0.0000; SP: H=12.57246, p=0.0019) (Fig. 7). However, deepening these analyses with a post-hoc test revealed that only the faces from layer 3 (top) differed significantly from the faces of the bottom layer (1) and the middle layer (2) – equally in pine and spruce wood. However, no significant differences were found between the bottom (1) and middle (2) layers. There were also no significant differences in the soft rot area on pine rollers' faces between the initial and final measurement (after 54 months) (Fig. 8). However, significant differences were found on the faces of spruce rollers (p=0.0000).

The rate of wood decomposition depends on its species, with the most current knowledge about spruce wood decomposition. Studies conducted in southeastern Norway have shown that spruce wood decomposes for about 90 years (Naesset, 1999), with significant effects on the decomposition of this wood being its diameter, surface area of contact with the ground, exposure, and soil moisture. Other Norwegian studies have shown that spruce and pine wood decomposition occurs after 60–80 years (Marikinen et al., 2006). Studies conducted in the Polish mountains have shown that the average minimum decomposition time of spruce wood in the upper montane zone is about 70–80 years (Zielonka, 2006). Similar studies in the Tatra Mountains have shown that the maximum decomposition of spruce wood occurs after a minimum of 60 years (Zielonka and Niklasson, 2001). In turn, on Babia Góra, it was found that spruce wood can lie for up to 160 years (Holeksa, 1998). The average time of decomposition of spruce wood on Babia Góra depended on the diameter of the wood and was 71 years for wood with a diameter of less than 23 cm, 90 years for wood with a diameter of 23–35 cm, and 113 years for a diameter above 35 cm (Holeksa

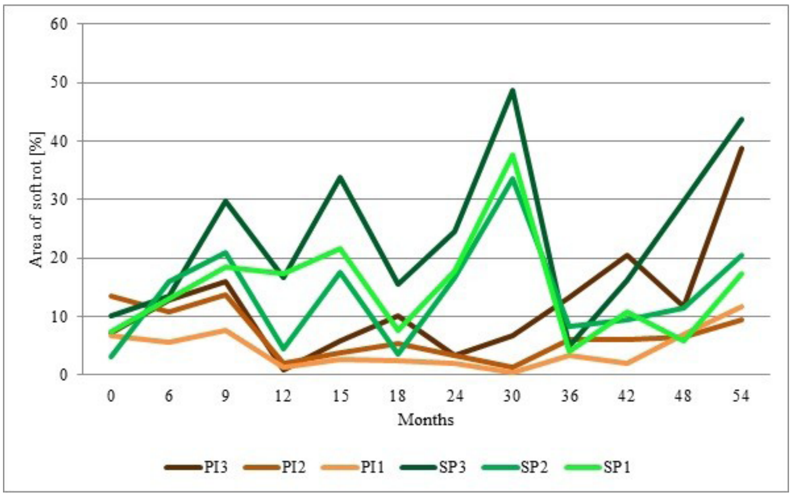

Fig. 7. Change in the area of soft rot in pine and spruce wood depending on the position in the layer (PI – pine, SP – spruce; 1, 2, 3 – layers)

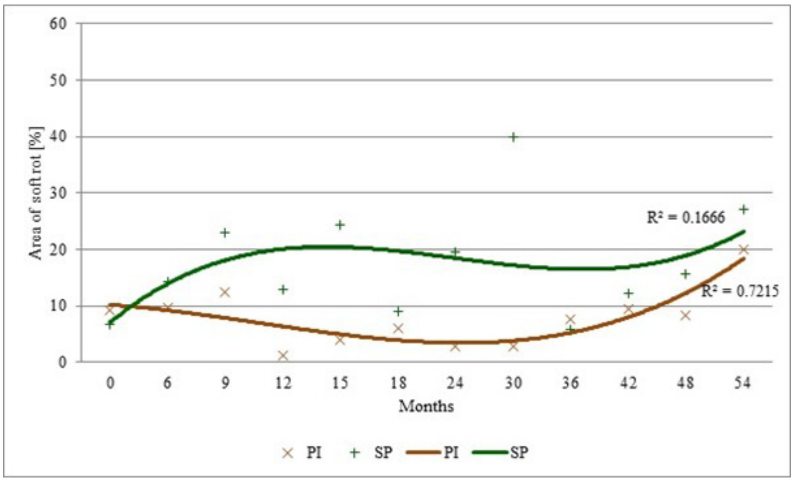

Fig. 8. Change in the soft rot area in pine and spruce wood on all test rollers combined

et al., 2008). These authors found that such a slow decomposition of wood is influenced by the low moisture content in the wood, which slows down the growth of wood-decomposing fungi. In this study, faster wood decomposition was also observed in the upper layer (SP3), where moisture from atmospheric precipitation had easier access to the wood. On the other hand, access to the wood in the lower and middle layers (SP1 and SP2) was more difficult, and the wood decomposition occurred much more slowly. Additionally, the wood in the SP1 layer was placed on sleepers, thanks to which it did not have contact with the soil, and additional air circulation caused faster drying of this wood and its slower decomposition. Other studies by the authors (Michalec et al., 2024b) conducted on external faces rollers showed that hard rot appeared on the faces of pine rollers only after 9 months. In spruce wood, the presence of hard rot was detected from the zero sample, and from that point on, the rot progressed quite rapidly. After just 18 months, the faces of some rollers were completely covered with rot. In most cases, the largest areas of hard rot were found in the upper layers. In the case of soft rot on pine wood, isolated cases were noted only after 12 months, and the increase in the area of this rot was gradual. In spruce wood, the presence of soft rot was noted after just 6 months, and from the 24th month onward, the number of faces with this rot increased dramatically.

Conclusions

By analyzing the changes on the test rollers' faces, the following conclusions can be drawn:

1. On the fronts of pine and spruce rollers, an increase in the area covered by blue stain was initially noted. In pine, this increase occurred until the 9th month, and in spruce until the 18th month of storage. After this period, the area of blue stain began to decrease, and this trend continued until the end of the study.

Table 3. Descriptive statistics of the percentage of soft rot on the test rollers' faces

Months	0	6	9	12	15	18	24	30	36	42	48	54
						Pine (PI)						
Average [%]	9.15	9.65	12.38	1.29	4.03	5.98	2.83	2.75	7.50	9.45	8.31	19.86
Median [%]	0.00	3.11	6.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Min [%]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max [%]	76.88	74.60	74.93	19.79	63.57	66.03	35.27	68.33	89.69	90.39	90.16	99.36
SD [%]	17.24	13.80	16.55	3.84	9.44	13.42	6.67	8.42	18.02	21.27	20.68	28.20
CV [%]	188.38	143.04	133.61	296.69	234.11	224.29	235.80	306.47	240.40	225.12	249.01	141.98
						Spruce (SP)						
Average [%]	6.76	14.13	23.00	12.84	24.24	8.90	19.59	39.88	5.79	12.14	15.62	27.11
Median [%]	0.00	0.00	12.49	6.29	20.10	0.00	16.13	39.69	0.00	10.63	4.86	22.85
Min [%]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max [%]	72.09	100.00	100.00	54.48	90.93	77.08	99.17	93.56	65.99	83.59	100.00	100.00
SD [%]	15.21	25.70	28.59	16.04	24.11	13.79	19.71	27.08	12.87	14.03	23.62	26.79
CV [%]	224.91	181.91	124.30	124.95	99.47	154.97	100.59	67.90	222.14	115.55	151.18	98.84

2. Hard rot initially showed an increase in the rot area (up to 18 months), and then this area started to decrease. In spruce, the area increased up to 6 months. In spruce, the surface increased until the 6th month. After this period, the surface of rot began to decrease. This resulted from the transition of hard rot to soft rot, which did not change the surface of the rot but changed its type.
3. Soft rot of pine and spruce wood showed great variability in the areas affected by this rot in the subsequent months of the study. However, in the final stage of the study, an increase in the area of fronts affected by soft rot can be observed.
4. In most of the analysed cases, the largest areas of oft rot were found in the upper layers (PI3 and SP3). This could be due to easier penetration of moisture from atmospheric precipitation into the rollers located in the upper layers of the piles, which resulted in increased wood moisture and thus better conditions for the development of rot fungi.
5. The fluctuations in the surface of the faces affected by both blue stain and rot (hard and soft) resulted from the fact that each time a new disc was taken for measurement (from the same roller), which caused the measurement location to also shift (change).
6. Based on the research carried out, it can be stated that the process of decomposition of pine wood occurs, but it is very slow. In the case of spruce wood, the process of its decomposition is more intensive than pine wood, and it is particularly visible after 18 months of storage.

Acknowledgements

This Research was financed by the General Directorate of the State Forests, topic no.: OR.271.3.5.2016.

Conflict of interest

The author(s) declare(s) that there is no conflict of interest concerning the publication of this article.

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