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CONNECTION BETWEEN SHAPE OF PINE (*PINUS SYLVESTRIS)* CONES AND WEIGHT, COLOUR AND NUMBER OF SEEDS EXTRACTED FROM THEM

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ABSTRACT

The article presents the attempt to establish connections between the shape of cones and the weight, number and colour of seeds coming from one stand. The author suggested choosing pine (*Pinus sylvestris)* seeds of the best cultivation characteristics before extraction, paying attention to the shape of cones, and after extraction basing on the weight and colour of seeds. In addition, the author studies the distribution of dark and light seeds on cone scales.

Key words: pine, cone, seeds.

INTRODUCTION

The cones of pine (Pinus sylvestris) show a big differentiation of size. Their length ranges from 1.9 to 7.0 cm and diameter is between 1.2 and 3.2 cm [5]. These parameters are interrelated [7]. The size of cones is variable and depends on many factors such as climate, soil fertility, type and age of stand or location of cones in a tree crown.
The cones of pine (*Pinus sylvestris*) tend to have different colours. The most common are black, brown, grey, many-coloured and fawn. In each of these groups of seeds of the mentioned colours there are full (vital) seeds and empty – barren, with the latter being usually of lighter colour [13]. According to Pravdin [11] and Suszka [12] any given tree develops seeds of the same colour. Suszka [12] claimed that the colour of seeds can be slightly different in subsequent seed years. Grzywacz [8], quoting Cerepin [6], stated that pine trees growing in infertile and dry habitats have cones with lighter seeds while those from fertile and wet habitats have darker seeds.

The research by Pichelgas [10] shows that the colour of seeds influences the quality of seedlings. The seedlings coming from black seeds are about 20% bigger than seedlings from lighter seeds, have a longer fibula and a bigger diameter in a root neck. Investigating ten-year-old pine cultivations derived from black seeds he proved that they were 8 to 13% higher than those from brown seeds.

Pichelgas's research shows the usefulness of segregating pine seeds and choosing those of better cultivation characteristics, quality of seeds is especially important for single sowing [9].

Daszkiewicz [7] made such an attempt and he divided cones into three groups according to their length: less than 4cm, between 4 and 5cm, and more than 5cm, and after that he weighed the seeds extracted from them. The seeds from the biggest cones were more than 20% bigger and heavier than those extracted from the smallest ones. Daszkiewicz sowed the above mentioned groups of seeds in a nursery and after five months he tested the seedlings. He stated that on the area of one hectare there were 3889 thousand good seedlings (I and II quality class) coming from the seeds of the biggest cones and only 1202 thousand seedlings from the seeds of the smallest ones, which is three times less. Daszkiewicz's research proves that the size of seeds is important in cultivation, bigger cones contain better seeds.

The question is when to segregate seeds: before extraction considering the size of cones – as Daszkiewicz suggests in his research, or after extraction choosing the seeds of the biggest weight or particular colour – as it is in the investigations by Pichelgas.

The aim of the above consideration is to find connections between the size (shape) of cones and the weight, number and colour of their seeds. Such connections can be a basis to obtain the seeds of better cultivation characteristics. The important information is also the distribution of vital and barren seeds in cones.

The presented analysis of research material (cones and seeds extracted from them) is only introductory as it covers the seeds of one stand and of limited number.

METHODS OF INVESTIGATIONS

The investigated collection of pine (Pinus sylvestris) cones consists of 83 cones which were taken directly from the extraction laboratory in the Łochów Forest District in 2002. They all came from the pure seed stand (Łochowska pine – 403).

Before extraction the following morphological features of the cones were defined: length, the biggest diameter (thickness), the number of disks – in closed cones and after extraction the number of open and closed scales, initial mass and the calculated index which is the proportion of length to diameter (thickness) of cones. This index was then used to determine the shape of cones. According to Pravdin's classification [11] cones are long if the index ranges between 2.5 and 3.0, long and thick – between 2.0 and 2.5, egg-shaped from 1.5 to 2.0, and round from 1.0 to 1.5. Figure 1 shows exemplary cones of three groups, occurring in the investigated collection, of different shapes (there were no round cones). The cone dimensions were determined with the use of slide calipers (accuracy 0.1 mm), while the mass – with the use of laboratory scale (accuracy 0.01 g).

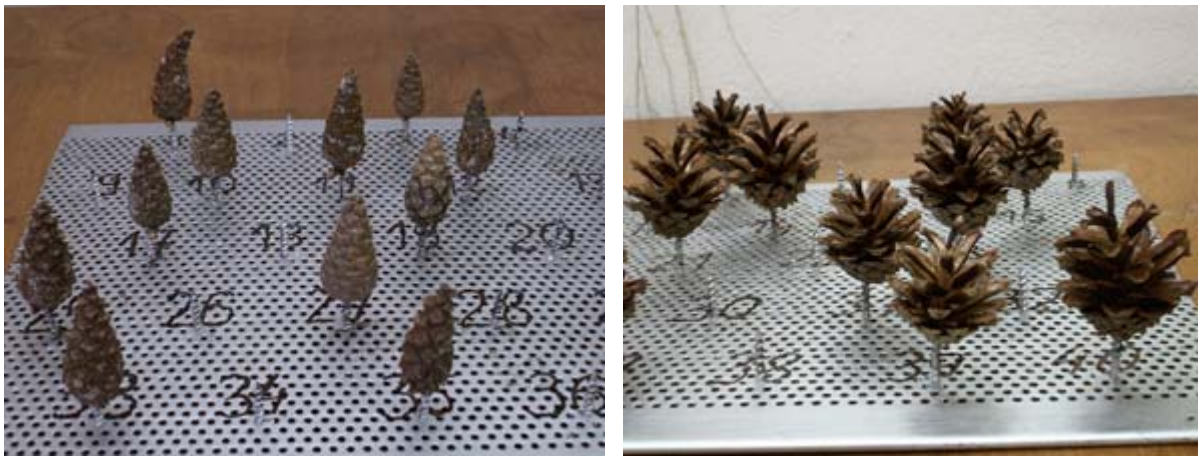
Fig. 1. Pine (Pinus sylvestris) cones of different shape after extraction: a – long, b – long and thick, c – egg-shaped

a. **b.** **c.**

Cones for extraction were stuck on pins attached to a special plate for investigation (Fig. 2). Thanks to this method, throughout the whole period of drying the cones were placed vertically and the seeds did not change their location during the process of scale opening.

For the cones extracted in the above described way it was possible, when the seed extraction process was completed, to count the number of open scales, to determine the location of each seed on subsequent scales in the cone, and to determine its colour and mass. The mass was determined with accuracy 0.0001 g.
The colour of seeds was determined immediately after extraction, dividing the seeds obtained from each cone into two groups: dark (of relevant colour) and light.

Fig. 2. The picture of the plate with stuck cones: a – before extraction, b – after extraction



a. **b.**

The process of seed extraction lasted for about 6 hours. It was carried out at constant temperature 58°C and average drying air humidity 9%, so in the conditions ensuring vitality of the obtained seeds [3, 4]. To confirm this state, in the final stage of the investigations, seed germinative energy and germination capacity was tested according to valid standards. For this purpose the seeds of each colour were sowed separately on a germinating bed of Jacobsen type, on the layer of filtrating blotting paper and covered with plastic hubcaps. There was constant temperature 24 ± 1°C. The pine seeds were additionally exposed to artificial light for 8 hours a day. Their germinative energy was determined after 7 days and germination capacity after 14 days (the testing was prolonged to 21 days according to ISTA standard) [2]. To test germination capacity the researcher used additionally seeds of different colours (black, brown and grey) extracted from the cones which were obtained from the same place and in the same time as those described in the article. The general criteria of seed classification are presented in Table 1.

Table 1. Vitality of pine (Pinus sylvestris)

Quality class	Germinative energy (%, at least)	Germination capacity (%, at least)
1	85	91
2	70	81
3	50	70

On every cone there is the height h_1 marked starting from the top and h_2 starting from the bottom of the cone which determine the limits of seed occurrence.

To determine the number of seeds in a cone of a particular shape, the index k was introduced which is the proportion of the number of open scales in a cone to the number of the seeds extracted from them.

RESULTS AND THEIR ANALYSIS

Dimensions of investigated cones in a closed state were as follows: length from 2.85 to 6.24 cm, diameter (thickness) from 1.46 to 2.40 cm, total mass before extraction between 2.85 and 12.0 g. These ranges are contained in the limits characterizing this species in Europe. The form of cones was determined basing on the shape of the majority of scales. Two cone forms were observed: plana and gibba. It was proved that 80 % of investigated cones was of the plana form.

Having applied Pravdin's classification as the parameter determining cone shapes, out of 83 cones 26 were classified as long, 50 – long and thick and 7 – egg-shaped. There were no round cones in this set. Average characteristic parameters for the cones of different shapes subjected to the investigation are presented in Table 2.

There was the biggest number of scales in egg-shaped cones – 7% more than in the other groups, 10% more open and 5% more closed scales than in long and long and thick cones. The degree of pine cone opening was: 0.41 for long cones, 0.42 for long and thick and 0.43 for egg-shaped, which proves that a slightly bigger number of scales opens on long and thick and egg-shaped cones than on long ones.

Table 2. Characteristic parameters of cones of different shapes

Cones	Number of cones	Average length [cm]	Average thickness [cm]	Pravdin's index	Average mass [g]	Average initial moisture content [%]	Average number of scales after extraction	
							all	open
Long	26	5.12	1.96	2.6	6.11	25.0	63	26
Long and thick	50	4.45	2.03	2.2	5.79	23.0	64	27
Egg-shaped	7	3.74	2.09	1.8	5.00	23.4	68	29
All	83	4.60	2.01	-	5.82	23.7	64	27

In every cone there were dark seeds of only one colour: black, brown or grey, there were no many-coloured and fawn seeds at all. In the group of long cones there were 10 cones with black and 10 with brown seeds (which amounted to approximately 38.5%) and 6 cones with grey seeds (23.0%). In the group of long and thick cones there were 30 cones with black seeds (60.0%), 11 with grey seeds (22.0%) and 9 with brown ones (18.0%), while among the egg-shaped cones there was one cone with black seeds and one with grey (14.5%), and 5 cones with brown seeds (71.0%). In this investigated group the cones of long and thick shape had mostly seeds of black colour whereas egg-shaped of brown colour (Table 3).

Table 3. The number of cones in the group with seeds of different colour

Shape of cones	Number of cones with seeds of following colours					
	black	%	brown	%	grey	%
Long	10	38.5	10	38.5	6	23.0
Long and thick	30	60.0	9	18.0	11	22.0
Egg-shaped	1	14.5	5	71.0	1	14.5
All	41	100	24	100	18	100

The above mentioned groups of dark seeds were always accompanied by the seeds of distinctly lighter colour, which were classified as light. On particular cone scales there were either two dark seeds or two light seeds, or one dark and one light seed. Frequently in such a case, there was one fully developed seed and the other was a wing with the underdeveloped seed. On some scales, especially at the top and the bottom of the cone, there were no fully developed seeds at all but only the wings. This leads to the conclusion that seeds occur mainly in the middle part of cones.

The description of extracted seeds for the cones of different shape is presented in Table 4.

Table 4. Characteristics of investigated seeds extracted from cones of different shapes

Seeds		Average number of seeds in cones			Average mass of a seed in cones		
		long	long and thick	egg-shaped	long	long and thick	egg-shaped
		number			g		
black	dark	18	20	23	0.0070	0.0062	0.0063
	light	13	8	10	0.0022	0.0021	0.0019
brown	dark	21	21	25	0.0067	0.0052	0.0055
	light	7	6	5	0.0021	0.0018	0.0020
grey	dark	17	18	15	0.0062	0.0065	0.0047
	light	8	9	4	0.0027	0.0024	0.0019
whole set (weighted average)	dark	19	20	24	0.0067	0.0061	0.0055
	light	10	8	7	0.0023	0.0021	0.0020

In the investigated group of long cones there were on average 29 seeds in each of them (that is 19 dark seeds and 10 light ones). Long and thick cones had on average 28 seeds per each (20 dark and 8 light seeds). The relatively biggest number of seeds was extracted from egg-shaped cones since there were on average 31 seeds in each such a cone, among which 24 were dark and 7 – light. On average, black seeds were the most numerous in egg-shaped cones (nearly 28% more than in long cones and 15% more than in long and thick). In egg-shaped cones there were 19% more brown seeds than in long and long and thick cones while in long and thick cones there were 20% more grey seeds than in egg-shaped and 6% more than in long ones.

In long cones the seeds of light colour amounted to 34% of all seeds, in long and thick cones it was 29% and in egg-shaped – 23% which is 32% less if compared to long cones.

In these investigated groups of cones the percentage of the mass of all the seeds extracted from particular cones to the mass of a dry cone amounted to, respectively, 1.83% for long cones, 1.93% for long and thick, and 2.29% for egg-shaped ones.

The percentage of the mass of dark seeds to the mass of a dry cone was highest for egg-shaped cones and amounted to 2.6% (about 20% higher than for the seeds obtained from long and thick, and long cones). The average mass of a dark seed in long cones was 0.0067g, in long and thick cones – 0.0061g, and in egg-shaped ones – 0.0055g. These last seeds were 20% lighter than the seeds from long cones, yet (for the investigated set of cones) statistically there were no significant differences, on the level $\alpha = 0.05$, between their mass and mass of the seeds from the other groups. The average mass of a light seed was 0.0021g, so it was almost three times lower than that of a dark seed, which probably suggests that these seeds are empty (barren), incapable to germinate.

There was research on germinative energy and germination capacity of seeds belonging to the groups represented by a given colour done to prove the above supposition. Eventually the dark seeds germinated as follows: black in 97%, brown in 96% and grey in 85%. The light seeds, for the three investigated groups, germinated in 2%. The conclusion is that dark seeds (black and brown) can be classified as quality class I and grey – as quality class II. Light seeds are not suitable for sowing. After conducting variance analysis on a bigger group of seeds (all coming from the same set) it was stated that, on the level of importance $\alpha = 0.05$, the colour of seeds is likely to influence their germination capacity.

Describing the average mass of a dark seed obtained from the cones of various shapes, one can easily observe that the black seed is 5% heavier than the brown seed and 13% heavier than the grey one, but the statistical analysis of these sets showed no significant differences also between the masses of the seeds of various colour (which can be ascribed to too small a set).

Analysing the influence of length and thickness of cones upon the mass of seeds one can state that longer and thicker cones have a bigger mass of seeds, thus the mass of a single dark seed is bigger, which was proved statistically ($R = 0.4614$).

In the below described example of seed distribution the subsequent scales were given numbers starting at the top of the cone to its bottom. From the long and thick cone of the length 4.42 cm and the thickness 1.97 cm having 66 scales (out of which 28 opened) there were extracted 35 seeds, among these 22 dark – black. On the first scale there were no seeds or wings, on the next four scales (No 2 –5), and on the last three (No 26 –28) there were only wings, without fully developed seeds. The first light seed occurred on the scale No 6, the next scale had one dark (black) seed. On the scales No 8 and 9 there were two seeds on each (one light and one dark). On the scale No 10 and 25 there were only dark seeds. On the scale No 11, similarly to No 14, 17, 22, 23 and 24, there were also two seeds of different colour on each scale. In the middle part of the cone on the scales No 13, 15, 16, 19, 20 and 21 there were two dark seeds, while on the scale No 12 – two light seeds (Fig. 3).

Fig. 3. Distribution of light seeds, dark seeds and wings on subsequent cone scales

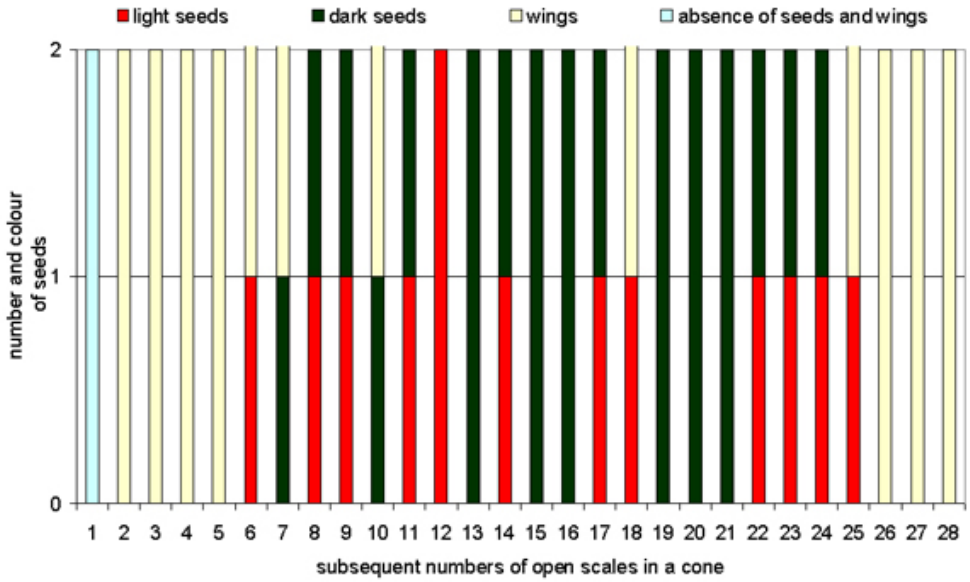
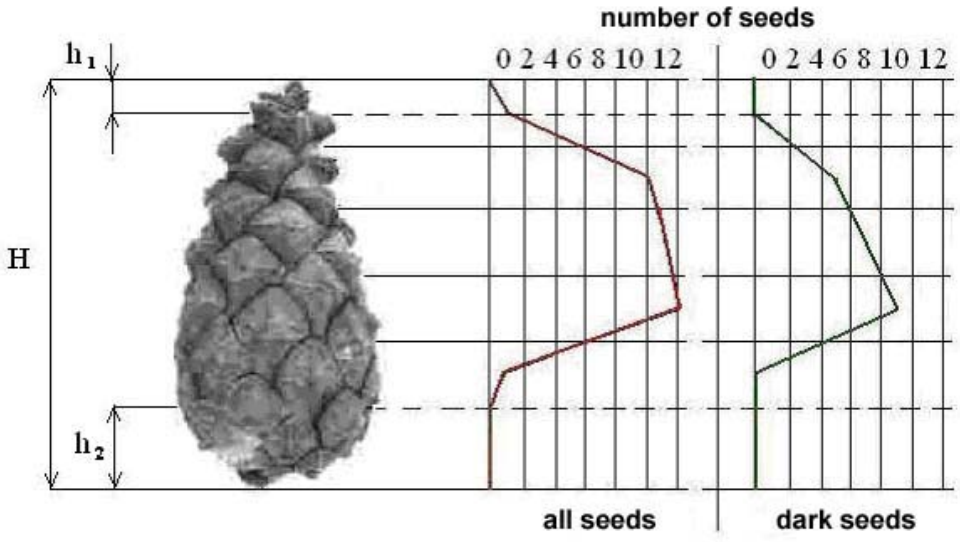


Figure 4 presents the location of seeds at a given height of a cone corresponding to the above description. The red line marks the number of all seeds, whereas the green – the number of dark (black) seeds depending on the location of scales in the cone. It is easily observed that in the upper and lower part of open scales there are two seeds of different colours on every scale: one light seed, mostly barren (empty), and one dark seed – largely vital, and in the middle and lower part there are two dark seeds on each scale (mostly vital, capable of germination).

Dimensions h_1 (in the upper part) and h_2 (in the lower part) (Fig.4) mark the absence of vital seeds. For the investigated set of cones the dimension h_1 is 8mm and h_2 is about 10 mm.

Fig. 4. Location of all seeds (red line) and dark seeds (green line) at the height of cone H



Index k for different shapes of cones amounts, on average, to 1.07, in the case of the segregation according to colours, for the cones with brown seeds it is 1.06, with black seeds – 1.01 and with grey ones – 1.13. This suggests that there are fewest seeds in the last group. Investigating the dependence of the defined coefficient k upon the length and thickness of cones one can easily observe that bigger cones have more seeds, because this coefficient is then lower.

The description of the distribution of light and dark seeds on cone scales for the selected colours (black, brown and grey) is not significantly different for the investigated groups. In every set not all the open scales contain fully developed seeds.

The above presented considerations allowed to confirm Daszkiewicz's recommendations [7] that before extraction cones should be selected according to their length choosing the longest ones because they contain seeds of a bigger mass, which presumably means of better cultivation characteristics. Classification according to cone shape that was presented by Pravdin [11], would make it possible to obtain seeds of particular colours, because long and thick cones would contain mostly black seeds having, according to Pichelgas [10], better cultivation characteristics.

Basing on the research conducted by Daszkiewicz and Pichelgas one can make an attempt of a two-stage procedure. The first stage – before extraction – bases on the choice of the longest cones, which also means the seeds of the biggest mass. The second stage – after extraction – is to conduct mass separation of seeds using, for example, pneumatic separators [14] and then to select black and brown seeds which are considered the best (separation according to colour).

CONCLUSIONS

1. The presented investigations show that both dark and light seeds occur in every pine (*Pinus sylvestris)* cone. In the studied set of cones there was always one dark colour: black, brown or grey.
2. Long cones (according to Pravdin's classification) most frequently have dark seeds which are either brown or black, long and thick cones – black seeds, and egg-shaped – brown.

3. It is advisable before extraction to segregate long and long and thick cones possessing seeds of better cultivation characteristics, or after extraction by choosing the seeds of the biggest mass and obtained from the longest cones – what is suggested by Daszkiewicz – and being of black colour – as Pichelgas recommends.
4. Not all open scales contain seeds. On the first upper scales and the last lower scales there are no seeds or they occur occasionally.

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