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THE RELATIONSHIP BETWEEN THE VIABILITY AND GEOMETRIC CHARACTERISTICS OF BEECHNUTS (*Fagus silvatica* L.)*

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ABSTRACT

The present demand for beech seeds in Poland has stabilised at a level of about 80 - 85 tonnes per year. Economy of the forest nursery production requires seeds of high genetic quality and good germination value. The geometric parameters of the seeds form the basis for selection. The size of seeds, as their most important physical property, has a particular importance during the evaluation of their viability, as well as in the process of cleaning and storage. The aim of this paper is the analysis of the geometric characteristics of the nuts of the European Beech, and the relationship to their vitality. The vitality has been determined on the basis of an evaluation of embryo-development by X-ray analysis. Measurements of the geometric parameters were made using computer- aided image analysis. A measuring device developed in the Department of Forest Works Mechanisation of the Agriculture University in Cracow was used. Results of the studies are presented in the form of tables and histograms, dividing the seeds into three vitality classes.

Key words: separation properties, geometric properties, sorting process, beech seeds

INTRODUCTION

The eastern border of the natural habitat of the European beech (*Fagus silvatica* L.), one of the basic forest-forming species passes through Poland. On average, beech occupies 4.4% of Poland's area, but in elevated and mountain areas it occupies up to about 15-20%. The present demand for beech seeds has stabilised at a level of about 80-85 tonnes per year. The total seed harvest in the beech productive areas and permanent seed stands fully supplies the needs of the State Forests. Nevertheless, the area of the existing seed base does not allow for an emergency reserve (in case of fire, pest depredations, or wind damage) [4]. The increase of periods passing

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between subsequent good-crop years imposes the necessity for the more rational use of seeds. Moreover, improvement in the knowledge as how to lengthen periods of seed storage is needed. It should be also remembered that seed ageing is the more intense if the quality at the beginning of storage is poor [10].

Because there are some problems with the natural regeneration of beech by seeding, the use of the full germinative capacity of seeds and the planting of a maximum number of seedlings from the seeds is becoming increasingly important in the forestry [3]. Because of strict regionalisation and the harvesting of seeds from a limited number of selected trees, tree stands and seed plantations, and because of permanently increasing demands for forest planting and regeneration, it is necessary to obtain the highest possible number of seedlings from a limited number of seeds [8].

The economics of forest nursery production requires seeds of high genetic quality and high germinative capacity. Therefore only the best quality seeds should be stored to form a reserve for years of bad crops, the prolonged storage of seeds to maintain the gene pool of the species (Forest Gene Banks), as well as for sowing and other direct applications [10]. Such a policy is aimed to result in a reduction of the overall costs of the planting material. Moreover, it will improve the use of areas designed for the intensive production of such material. Therefore, the crucial problem is concerned with the separation of seeds that would provide planting material of a higher quality. The separation process selects full, correctly formed seeds from empty or damaged ones [7, 9]. Obtaining high quality planting material requires a good knowledge of the rules governing the separation processes, based mainly on differences in some of the physical properties of the seed mixtures particular components. Also the design and exploitation of the machinery and equipment for the treatment and cleaning of seeds demands such knowledge [1].

THE AIM AND SUBJECT OF THE STUDIES

Geometric parameters may form a basis for the seeds separation traits. The size of seeds, as their most important physical property has a particular significance in the evaluation of their viability and in the processes of cleaning and storage. In the separation processes the thickness is important when using sieves with longitudinal holes, and the width for sieves with circular holes. The surface areas of seeds (bearing surfaces) affect their aerodynamic properties, while the length/circumference ratio is often used for calculating their shape. Measurements of some geometric characteristics of beech seeds have been carried out in a few works, but the lack of any correlation between those parameters and the biological properties of the seeds has prevented the practical application of these results.

The aim of this work is an analysis of the above mentioned geometric characteristics of beechnuts in correlation with their viability. Seeds from the following sources were studied: - Bielsko Forest Division, Forest Section - Salmopol; crop year - 2000; viability - 68%; humidity - 9.8 %; mass of 1000 seeds - 249.8 g.
The computer aided image analysis used in measurements requires the preparation of an appropriate algorithm, which would distort the size, and shape of the visualised seeds on the digital images to the least extent. The present study also embraces this task.

METHODS

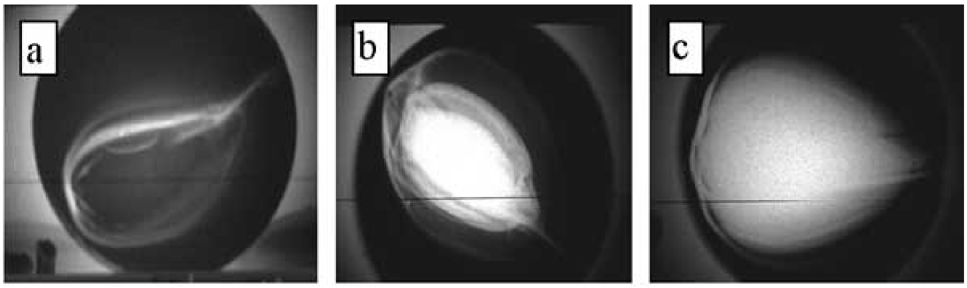
The methods of investigation applied involved measurements of particular parameters for single seeds. Seed viability was determined on the basis of an evaluation of the development of embryos after X-ray examination [6]. Each seed was X-rayed, using FAXITRON X-Ray systems 43855A apparatus. The X-ray tube was operated at 14 kV. The time of exposure was 81 s [9]. To enable identification the seeds were placed, before X-ray examination, on a plexiglass (metaplex) matrix (Fig. 1). This part of the studies was done in the laboratory of the Forest Gene Bank in Kostrzyca.

The standards used to calculate the expected germination ability of the deciduous species were consistent with the rules for seed evaluation as used in the State Forests. The investigated batch of seeds was divided into three viability classes:

- I - empty, insufficiently formed and damaged seeds, unable to germinate (Fig. 2a) - class 0 and 2, according to the State Forest evaluation system [13],
- II - insufficiently formed seeds, partly able to germinate (Fig. 2b) - class 3, according to the State Forest evaluation system,
- III - correctly formed seeds, eventually with the embryo wrongly adhering to the shell, but fully able to germinate (Fig. 2c) - class 4 or 5, according to the State Forest evaluation system.

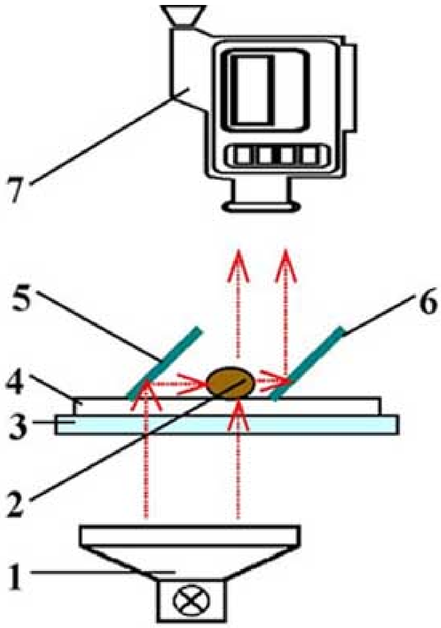
Figure 1. Beech seeds place in metaplex templed, prepared for vitality analyse by using X-ray radiography method

Figure 2. X-ray photography of the beech seeds: a – empty, b – undeveloped, c – full, correct formed



The authors' own software for the computer-aided image analysis was used in the studies of the geometric properties of the seeds. Measuring apparatus built in the Faculty of the Department of Forest Works Mechanisation, Agriculture University in Cracow was used for this purpose (Fig. 3). The JVC GR 9800 digital camera, with 1024x768-pixel resolution was used to take photos of particular seeds. The optical stand enabled photos of the seeds to be obtained in three orthogonal projections (i.e. three planes mutually at right angles), without the need to change the position. To achieve this a system of four plane mirrors was used, comprising two reflecting and two illumination mirrors. The mirrors were adjusted to an angle of 45 degrees to the plate on which the seeds were placed, mutually perpendicularly (to get a good readability, only one pair of mirrors is placed in the figure – the second one is situated perpendicularly). Such a system makes it possible to register on one photo the direct image of the seed, and its two reflections in both mirrors simultaneously. To assure equal illumination of all three views, necessary for correct analysis, one source of light was used, illuminating the seeds from the bottom and from both sides, light being reflected from the additional illumination mirrors. The system considerably increases the contrast of the image and facilitates its further analysis [2, 5].

Figure 3. Functional diagram of the stand for measurement of seeds geometrical characteristics;
1 – reflector, 2 – analysed seed, 3 – focusing screen, 4 – glass plate, 5 – illuminating mirror, 6 – projection mirror, 7 – video camera



The photos of particular seeds were subjected to a series of transformations preceding the qualitative analysis (Fig.4):

1. Scaling - done to determine the scale factor of an image. Because the projections of seeds are created at various distances from the objective, the scale factor of each image (projection) of the seed was determined separately. Scaling was carried out using the image of a sphere of known diameter.

2. Contrast normalisation - enables better differentiation of the details within the image, due to extension with a linear function of the points value to 256 grey scale points.

3. Median filtration – belongs to the group of filters analysing the intensity of particular, image-creating pixels, taking into account their local neighbourhood. The advantage is that it does not introduce any new values to the analysed image, which leaves the sharp edges of the image unchanged, but smoothes the jagged edges. It also totally eliminates the noise of the image (small, unwanted objects). The filtration was achieved using a structural element, of 5 x 5 pixels in size.

4. Conversion of octal to binary representation - it changes the 8-bit image to the 1-bit one (binary). The result of this operation is the image showing black objects (seeds) on the white background. This is necessary because the basis of such automatic measurements e.g. the number of the objects, area, or length, etc., is the black-white image.

5. Threshold search - identifies objects having arbitrary defined range of areas. These objects are then analysed quantitatively [12].

The accuracy of measurements resulting from the applied enlargement and picture resolution amounts to 0.085 mm in the case of linear quantities, and 0.00 mm^2 for the areas. The error of area measurement, resulting from the proposed algorithm of the image transformations is 1.3%. The circumference of the particular objects is accurate to within 10%. The image analysis, i.e. its transformation and measurements were carried out using the MultiScan v.6.08. computer program.

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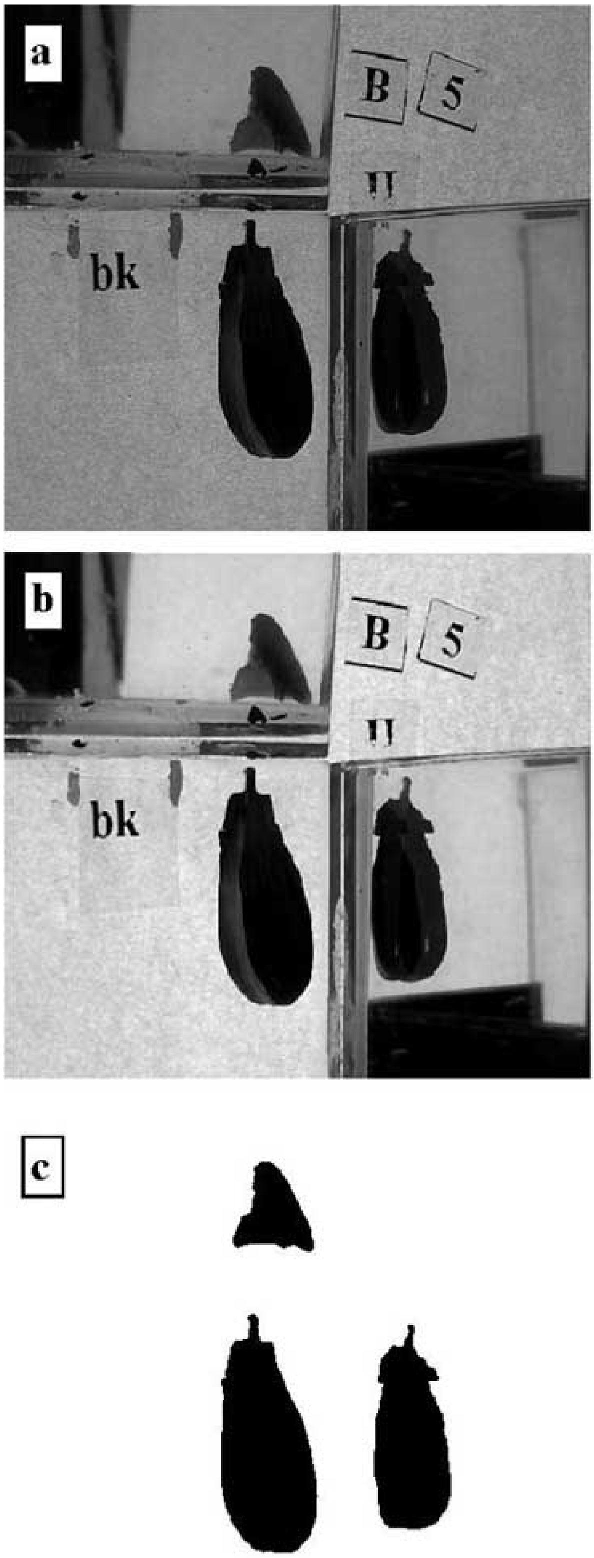
Figure 4. Successive phases of the computer image analyses:
a – 8-bit, digital initial image, b – after contrast normalisation and using mediana filter, c – after conversion to binary image and object isolating – prepared for quantitative analyses



RESULTS OF INVESTIGATIONS AND THEIR ANALYSIS

The geometric parameters of the beechnuts and their statistic analysis are presented in Table 1. Minimum, maximum, and average values, with a coefficient of variation, were taken into account. The particular values for seeds in the three earlier defined groups (viability classes) were taken into consideration. The significance of differences between the fractions was also evaluated using the t-Student test. It was found that the seeds from the higher viability classes had greater linear dimensions, but no statistically significant differences in the width/length ratios between I and II vitality classes were found. Similar results were obtained when comparing the cross-sectional areas and circumferences of the cross-sections areas. From a point of view of the mechanical separation of seeds the consideration of the average values in the classes is insufficient. It is necessary to know the range of the occurrence of a particular feature. Therefore it is reasonable to look at the maximum and minimum values. The lower limits of the occurrence of the seeds of particular geometric features (minimum values) are different, while the upper limits (maximum values) are almost identical for all viability classes. This makes effective separation by a one-stage system impossible.

The analysis of the geometric features variability shows that beechnuts are highly dimensionally uniform (low coefficient of variation). Correctly formed seeds show the lowest variability. The differences between the largest and smallest registered dimensions were equal to: 54% for thickness; 55% for width; 52% for length. Similar values (between 49% and 62%) were obtained for seeds circumferences, and slightly higher values (from 75% to 78%) for the sectional areas.

The histograms of the contribution of thickness and width of beechnuts (the dimensions directly used in the dimensional separation on sieves) are presented in Fig. 5. In the case of the thickness, three fractions including the seeds with dimensions varying from 8.58 to 10.49 mm form the largest proportion (almost 65% of the seeds investigated). For width, two fractions of dimensions varying from 10.46 to 12.03 mm contained almost 50% of the seeds. However in this case, the high number is caused both by the relatively high content of viable seeds and empty seeds. This makes the initial conditions less favourable when designing a separation process.

Based upon the histograms, the expected germinative capacity of the target seed fraction, and of the discarded fraction can be estimated, after assumption of an appropriate division limit. For instance, a division-line at thickness greater than 6.84 mm will increase the expected germinative capacity of the target fraction from 73.4% to 76.5%. The germinative capacity of the discarded fraction will then be 15.1%. In the case of a further shift of the division line in the case of a subsequent class, the respective values will be 78.6% and 29.1%. Adopting more extreme division-line values does not cause any significant improvement of the germinative capacity of the target fraction, but the number of viable seeds in the discarded fraction will increase sharply.

The linear dimensions of beechnuts are interrelated by some correlations - an increase of one of the dimensions causes some increase of the others. They are not functional relationships, but the correlation between thickness and width is very strong - the correlation coefficient reaches 0.725. On the other hand, the correlation coefficients for the thickness and width together with length are equal to 0.385 and 0.409 respectively. It may thus be stated that the shape of beechnuts is very stable, despite their considerable size-range.

Table 1. Geometrical characteristics of the beech seeds

Vitality clases	Statistical parameters						
	Average	Minimum	Maximum	Coefficient of variation (%)	Significant level		
					I - II	II - III	I - III
Thickness (mm)							
I	6.9	4.3	9.4	13.5	*	**	**
II	7.1	4.4	9.1	12.1			
III	7.6	5.9	9.4	9.2			
Width (mm)							
I	8.6	4.3	11.5	12.4	n	**	**
II	8.6	5.9	11.6	12.7			
III	9.2	7.0	11.5	8.9			
Length (mm)							
I	16.5	9.8	19.3	10.5	n	**	**
II	16.6	12.5	19.9	9.8			
III	17.7	15.0	20.3	7.5			
Section area in thickness and width cutting plane (mm^2)							
I	35.3	17.3	57.6	22.3	*	**	**
II	37.9	16.7	58.8	22.1			
III	44.0	25.0	66.3	16.3			
Section area in thickness and length cutting plane (mm^2)							
I	112.0	38.9	166.8	21.4	n	**	**
II	112.9	56.9	174.9	17.4			
III	125.8	86.6	162.6	12.8			
Section area in width and length cutting plane (mm^2)							
I	124.8	44.8	186.2	19.4	n	**	**
II	125.4	64.7	184.8	19.0			
III	143.7	85.3	190.1	12.9			
Section circumference in thickness and width cutting plane (mm)							
I	30.8	16.0	40.0	12.8	n	**	**
II	31,6	19,4	41,8	12,0			
III	33.7	26.4	41.9	9.3			
Section circumference in thickness and length cutting plane (mm)							
I	55.8	35.0	66.5	10.3	n	**	**
II	54.8	42.5	66.5	9.1			
III	57.9	46.5	67.2	7.6			
Section circumference in width and length cutting plane (mm)							
I	56.2	33.8	66.3	9.9	n	**	**
II	56.1	41.2	66.5	9.8			
III	59.8	46.6	69.9	7.6			

n – non-significant
*** – statistically significant differences at $p < 0.05$**
**** – statistically significant differences at $p < 0.01$**

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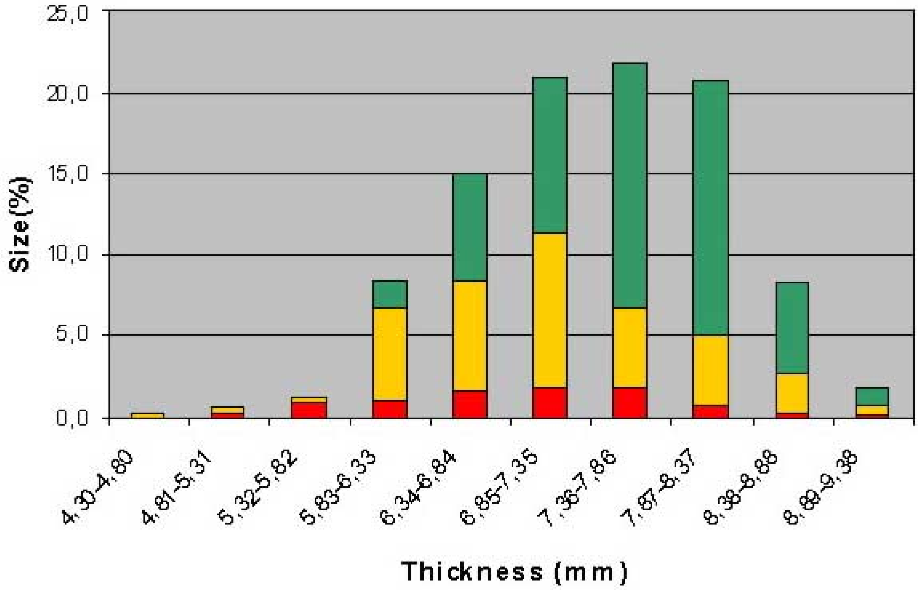
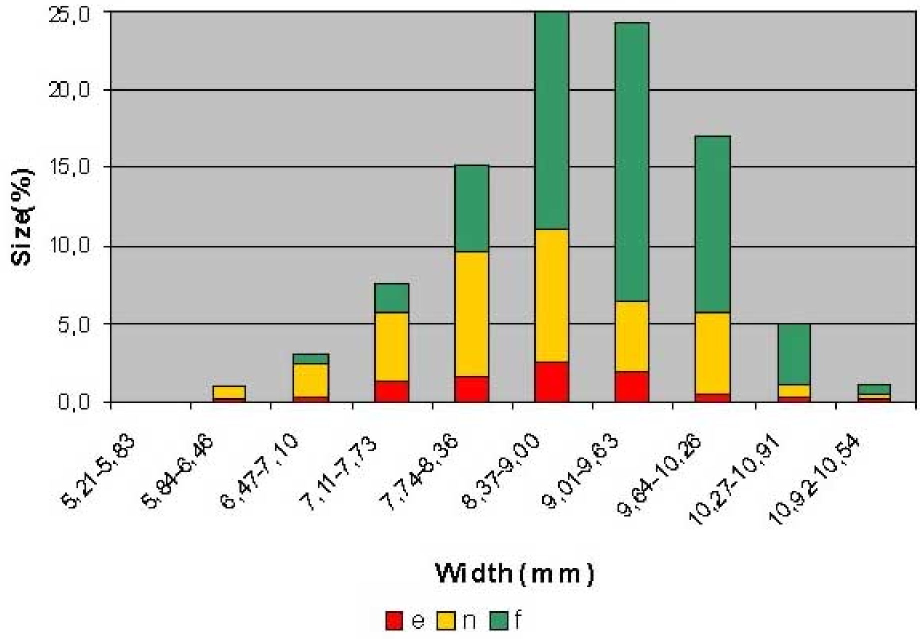
Figure 5. Histogram of the beech seeds distribution in the classes: a – thickness, b – width; e – empty seeds, n – undeveloped, f – full





CONCLUSIONS

1. For a studied population it was found that the geometric features of beechnuts might be considered as selective features. Therefore there exists some possibility of using them in designing methods for beechnuts mechanical separation. In general there are no possibilities to separate nuts in viability classes I and II.
2. The size of beechnuts is characterised by the three basic dimensions, which are mutually and positively correlated. The beechnuts belonging to the higher classes of viability are larger, and the variability of all their geometric features is smaller.
3. The method of investigation applied is laborious and time consuming, but it enables the precise determination of the correlation between the viability of the evaluated seeds and their particular physical features.

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