Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2003
Volume 6
Issue 2
Series FORESTRY

TYLEK P., WALCZYK J. 2003. CRITICAL AIR VELOCITY AS A SEPARATION FEATURE IN NUTS OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) **Electronic Journal of Polish Agricultural Universities**, Forestry, Volume 6, Issue 2.
Available Online http://www.ejpau.media.pl

CRITICAL AIR VELOCITY AS A SEPARATION FEATURE IN NUTS OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.)*

Paweł Tylek, Józef Walczyk
Department of Forest Works Mechanisation, Agriculture University in Cracow, Poland

ABSTRACT

Stands of European beech cover around 4.1% of the total forest area in Poland. In the Carpathians the share of European beech amounts to 25.9%. Long intervals between mast seed years in beech force foresters to optimize the seed management. The separation of seeds into various quality classes is usually done with devices working on the basis of physical properties of seeds. The goal of this work was to analyze the critical velocity of beechnuts in order to determine, if the aerodynamic properties of beechnuts can be used as a basis for their separation. The other goal of this work was development of an algorithm of computer-aided image analysis.

Key words: distinctive features, critical velocity, separation, beechnuts.

INTRODUCTION

Stands of European beech cover around 4.1% of the total forest area in Poland. In the Carpathians the share of European beech amounts to 25.9%; it is one of the most important tree species [5]. Seeds are produced every third year on average; mast years are separated by 6-12 year intervals. Long-term average need for beechnuts amounts to 80-85 tons per year, while the seed production is as follows:

a) an average variant: (assuming mast seeding every 7 years and mean seed production 40 kg/ha): 55–67 tons per year from the managed seed stands, 6.5–8 tons per year from the selection stands, 12 tons per year from managed stands in the regeneration phase;

b) the pessimistic variant (assuming the longest time without mast seeding equal to 8 years and the lowest seed production equal to 30 kg/ha): 45–52 tons per year from the managed seed stands, 3.5–4.4 tons per year from the selection stands, 8 tons per year from managed stands in the regeneration phase [2].

The increasing intervals between consecutive mast seed years in European beech force us to optimize the seed management and to prolong the time of seed storage [8]. To obtain good germination or to choose seeds for long-term storage we need to separate the fully developed viable beechnuts from the ones that are either empty or damaged. To do that, we need to learn more about the biological and physical properties of seeds which are suitable for germination.

Separation of seeds into quality classes is done with devices employing differences in physical properties of seeds. Therefore a detailed knowledge of these physical parameters, which can be used in seed segregation, is needed. The separation should be done in such way, to keep all the sound, viable seeds (large and heavy, small and light), because they are essential from the point of view of maintaining the genetic variability of species [7]. Optimization of the mechanical separation of beechnuts needs searching among many physical properties for a few which are promising for a fast and effective process of cleaning and separation of seeds [1].

Pneumatic devices are frequently used in the process of separation of seeds of forest trees. This is because pneumatic devices have many advantages. They allow for purification and segregation of seeds simultaneously, without changing the parameters of separation. Thus they can be considered universal devices. They do not damage the seeds and they do not alter their physical and biological properties in the process of separation. They are characterized by a high efficiency and they do not emit much noise. What is also essential, they do not cause any dust emission to the atmosphere (in case of aspirators), so they can be used no only in seed extractory but also in small laboratories.

The aerodynamic property of seeds which is used for seed separation in pneumatic segregators is the critical velocity (of flying). It is defined as a velocity of vertical air stream which keeps the seeds suspended in the air, which is a result of reaching a balance between the seed weight and the strength of the air stream [3].

THE AIM AND OBJECT OF STUDY

The object of study was analysis of the critical velocity in beechnuts, taking into account their belonging to certain vitality classes. We tried to answer the question, if the critical velocity is a good separation feature for beechnuts and what s the theoretical efficiency of separation based upon differences in that velocity. Another goal of this work was also developing an algorithm of the computer analysis of the image obtained by using the video camera as a research tool.

The objects of study were beechnuts of the Polish populations of European beech (*Fagus sylvatica* L.). Seed collection started in October 2000 in the Bielsko Forest Division, Salmopol Forest Section. Purity of beechnuts amounted to 96%, and their vitality (estimated on the basis of tetrazolium test) was 68%, which means that they belonged to the third class of vitality. The beechnuts were dried until the water content went down to 9.8%. Mass of 1000 seeds was equal to 249.8 g.

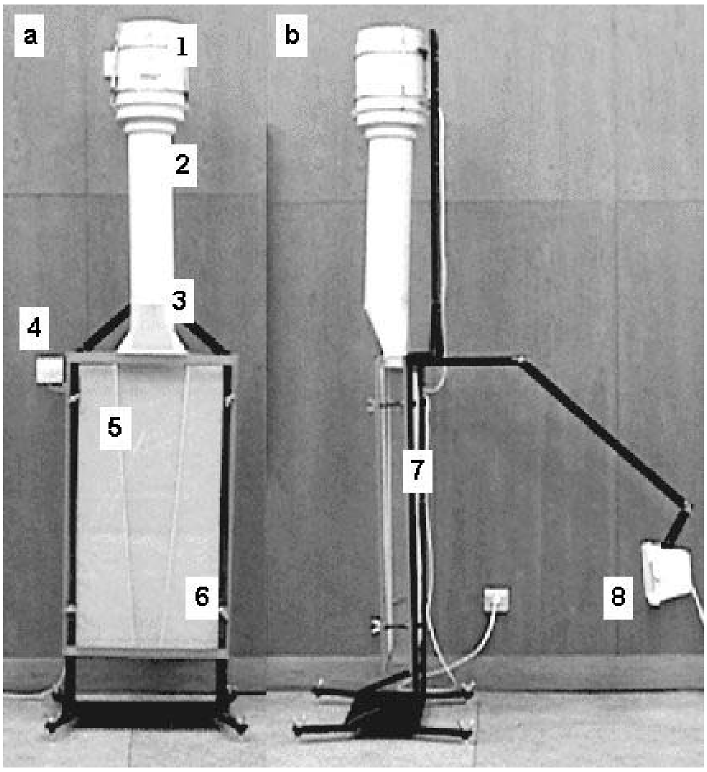
Apart from the direct measurements conducted in this investigation, we utilized a data base containing results from previous studies, including parameters like the, mass of individual beechnuts or their density [10]. Among those parameters there was also classification of the beechnuts into vitality classes, determined on the basis of the X-ray analysis of the embryo development [6, 12]. Beechnuts were divided into three classes:

- class I – encompassing the classes 0 and 2 according to the classification system used by the Forest Service [14] – seeds empty, insufficiently developed or damaged, unable to germinate,
- class II – ore of lees equal to the class 3 in the Forest Service system of seed classification – seeds insufficiently developed, partly able to germinate,
- class III – encompassing classes 4 and 5 in the Forest Service system of seed classification – seeds well developed or with the embryo not perfectly attached too the seed shell, fully viable.

METHODS

The classical method of determining the critical velocity is placing single nuts in a conical-shaped vertical channel with regulated air flow velocity; the height of suspension of beechnuts in the air is then determined. Commonly used are the channels with the source of air from below, what – despite installation of vibration dampers and guide rings – causes disturbances in the regularity of air flow. Because of the irregular shapes of beechnuts and situation of their gravity centers the beechnuts move in the tunnel along complex trajectories; they move forward along the walls of the channel and they rotate around their own axes. Therefore the height of suspension is usually defined as the maximum or the minimum height reached by the nuts. However, it is a simplification; according to the results obtained by the other authors, analyzed seeds frequently stay at certain preferred heights, only very seldom reaching the extreme positions [9]. Because of that, the classical way of conducting measurements was slightly modified in this study.

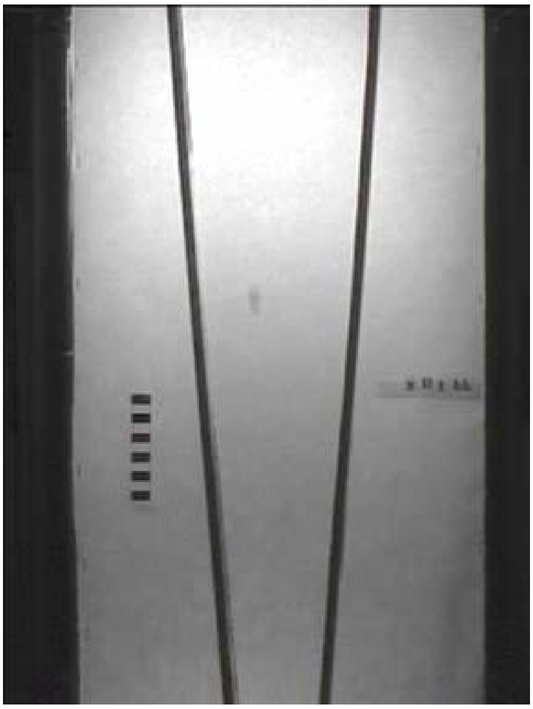
Figure 1. Aerodynamic tunnel: a – view from the front, b – view from the side: 1 – ducted fan with guide rings, 2 – compensatory channel, 3 – confusor, 4 – thyristor controller of the fan output, 5 – side walls of the tunnel, 6 – transparent front wall of the measuring tunnel, - the back wall of the tunnel with focusing screen, 8 – reflector



Measurements were conducted in the aerodynamic tunnel (fig. 1), constructed in the Department of Forest Works Mechanization at the Agricultural University of Cracow. The main part of the device is an observational tunnel of variable cross-section. The air flow which keeps the seeds suspended in the air is generated by the fan, which is connected to the system by a suction side. This enables the air to move into the observational tunnel from the outside. Such solution associated with the employment of the tunnel attenuating the pulsation of the fan results in a constant air flow at the entrance to the measuring tunnel. The regulation of the output of the fan is obtained by changing the rotational speed, using a stepless thyristor voltage regulator. For measuring the velocity of air flow with the accuracy of 0.02 m/s a tunnel hot wire anemometer produced by the British firm AIRFLOW was employed; the telescope probe of this hot wire anemometer was placed in the upper part of the tunnel.

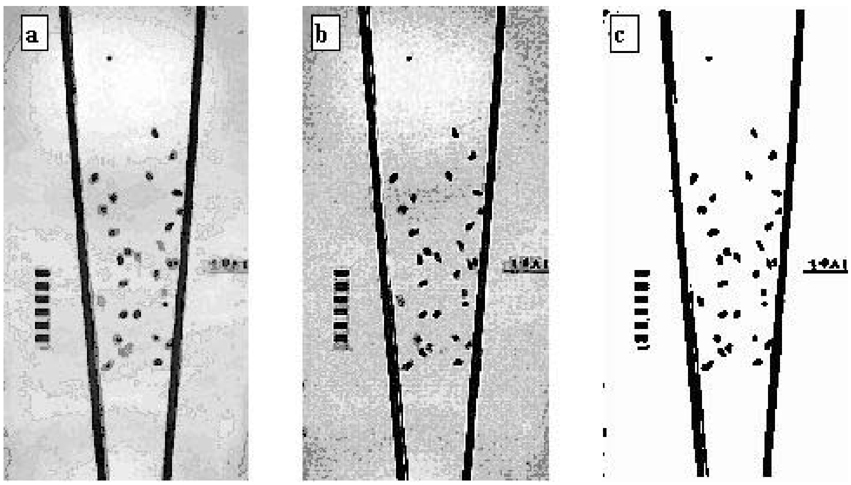
The beechnuts were placed in the tunnel individually, and their movements were recorded using the video camera JVC GR 9800 (video clip). Because of the shadows which made the further analysis difficult, the shadows of the beechnuts illuminated by a halogen reflector with a focusing screen were recorded [4].

Video clip: a research video-film recording the behaviour of a beechnut in the air stream



Then, using the MultiScan software, 30 frames of the film shot at 0.5 s intervals were superimposed, producing the image visible in figure 2a. After scaling the image it was subjected to a digital image analysis, based upon the normalization of the contrast and using the median filter. These treatments allowed for showing marker objects (beechnuts) against the bright background and diminish the information noise (fig. 2b). The next step was conversion from octal to binary representation, as a result of which one-byte image was obtained, presenting black objects against the black background (fig. 2c). Only such image could be analyzed in a quantitative way, based upon determining the geometric gravity centres and calculating the distances from them to the points, where the hot wire anemometer probe was placed. In places of consecutive locations of beechnuts the cross-section of the tunnel was calculated automatically; then the velocities of the air stream were determined using the stream continuity equation, and consecutively the mean velocity of air stream was calculated. This algorithm was applied for 300 beechnuts, each class of embryo development represented by 100 nuts.

Figure 2. Consecutive phases of the computer-aided image analysis: a – mixed film frames with sampling interval equal to 0.5 second, b – the image after normalization of the filtration contrast, c - the image after conversion from octal to binary representation, ready for quantitative analysis



RESULTS OF THE INVESTIGATIONS AND THEIR ANALYSIS

Results of the measurements of the critical air velocities were given in table 1. It presents the minimum values, the maximum values and the mean with the coefficient of variability. These values were presented for each of the three classes of seed vitality (embryo development). Significant differences among vitality classes were ascertained. The critical air velocity for fully developed beechnuts (class III) is larger than the critical velocity for beechnuts not fully developed (class II) by 10.7%, and larger by 29.0% than the critical velocity for class I (empty beechnuts). Apart from that, beechnuts were characterized by a large stability of their aerodynamic properties (low coefficients of variability). The lowest variability was found in the seeds fully developed; it was two times smaller than the variability in empty seeds.

Table 1. Characteristics of the critical air velocities for beechnuts

Vitality classes	Average [m/s]	Minimum [m/s]	Maximum [m/s]	Coefficient of variation [%]
I	7.70	4.88	10.25	13.9
II	8.97	6.27	11.28	9.3
III	9.93	7.79	11.58	7.0

While planning the mechanistic separation of seeds, taking into consideration only mean values for each vitality class would be insufficient. We need also to know the ranges of a given feature; thus we looked at the minimum and maximum values. The lower limits (minimum values) for seeds belonging for certain vitality classes were significantly different; however, the upper limits (maximum values) were similar, especially for seeds representing classes II and III. Therefore the effective segregation based upon differences in terminal air velocities would be a difficult task.

In figure 3 a histogram presented the share of beechnuts in certain fractions of terminal air velocities. These velocities were divided into 10 fractions, assuming the lowest recorded value to be the beginning of the first fraction and the highest recorded value to be the upper end of the lowest fraction. The percentage of empty seeds was largest in the fraction no 4, of seeds not fully developed – in fraction no 7, and of fully developed seeds – in fraction no 8. Such histogram could be very useful while designing the process of segregation of beechnuts in an air tunnel; on the basis of these results one could determine the optimal limit for the division of the particular mixture. On the basis of that histogram a nomogram was produced (fig. 4), allowing for the estimation of the viability of the target fraction and the rejected fraction, as well as for the determination of the losses associated with sorting process. Numbers of classes in figure 4 are the same as numbers of the critical velocity fractions presented in the histogram. One can say that rejecting three classes on the left hand side of the histogram would not cause a significant increase in the quality of the sowing material. However, it should be done, because we reject only empty seeds. Similarly, very low losses in valuable beechnuts were ascertained while setting the limit of segregation at the velocity of 7.55 m/s. In that case the percentage of seeds able to germinate was 12%, but no fully developed beechnuts were found in that fraction. Moving the separation limit to fractions no. 5 and no. 6 resulted in the increase of the germination ability of the target fraction seeds from 73.5% to 77.1 and 80.1%, respectively. The losses of the fully developed seeds would be negligibly small, but the percentage of germination ability of the rejected fraction would increase to 27.8% and 40.6%, respectively, mainly due to the substantial increase in the amount of beechnuts not fully developed. Moving the separation limit even farther could not be accepted because of ecological reasons, despite the fact, that this would increase the quality of the selected seeds. When setting the separation limit at the terminal velocity of 7.56 – 8.59 m/s, we would need to utilize the rejected sowing material. This results from the fact, that this material contains a lot of beechnuts not fully developed, but still able to germinate. In case of multi-stage separation we could suggest to separate two or three fractions from the right hand side of the histogram in the first step, and then to segregate the rejected material\ using different set of separation features, like density or seed size. The pneumatic separation is frequently used for dividing the whole set of seeds into weight fractions. We already know that the largest value for sowing have the seeds which are either very heavy or at least moderately heavy. However, the terminal air velocity is not functionally related to the seed mass; other factors, like the size of the bearing surface also play significant roles. The larger is the bearing surface, the smaller could be the air velocity necessary to lift the seed. On the other hand, large and viable seeds have also a large mass, and that is directly proportional to the terminal air velocity. Other investigations conducted by the authors [12] showed, that the size and shape of beechnuts are very stable features, similar among various classes of vitality (embryo development). Therefore we could assume that the differences in the values of terminal velocities are caused largely by the differences in seed mass. In figure 5 we presented the correlation between critical velocity and seed mass. Increase in the mass of beechnuts up to 250g (per one thousand nuts) caused significant increase in the terminal velocity. Increasing the seed mass farther did not cause such a significant increase in critical velocity – it stabilizes around 10 m/s. We suppose that at this stage the important role is played by the increasing bearing surface of beechnuts. This makes the effective segregation of largest beechnuts into weight fractions an impossible task. However, among the beechnuts exceeding the mass of 250g the fully developed ones dominate; so, separating them into fractions is not necessary from the pint of view of nursery practice.

Figure 3. Histogram of beechnuts in various classes of critical velocity; e – empty nuts, n- not fully developed nuts, f – fully developed nuts

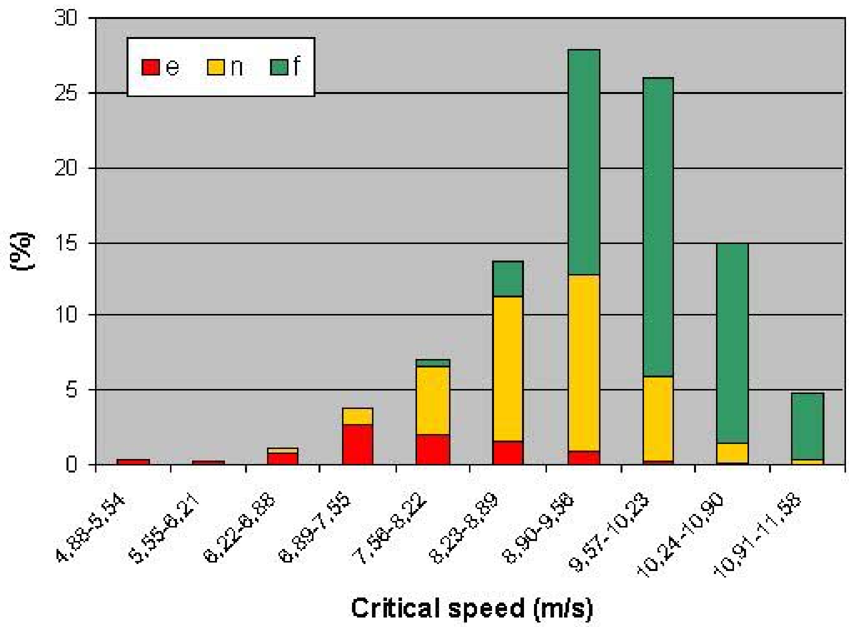


Figure 4. Nomogram of the assessment of efficiency of sorting beechnuts in a vertical air stream: A – percentage of germination ability in the fraction sorted target fraction, B – percentage of germination ability in the fraction rejected, C – losses of fully developed beechnuts

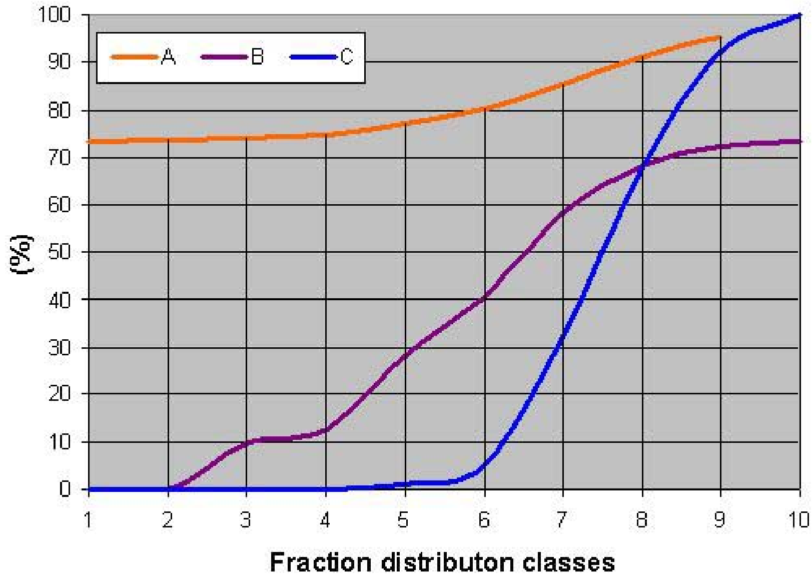
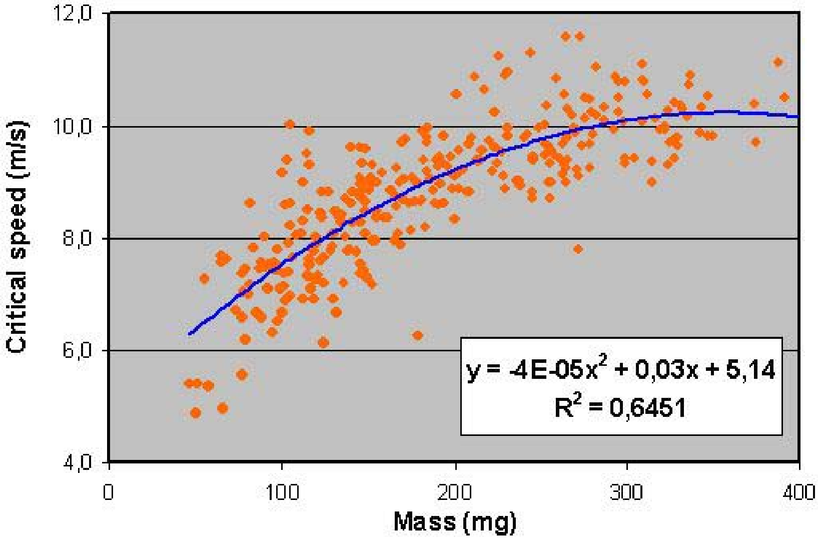


Figure 5. Relationship between the critical velocity of beechnuts and their mass



CONCLUSIONS

1. Critical velocity in beechnuts can be considered a separation feature and utilized in designing working elements in machines for cleaning and sorting seeds as well as for optimization of the process of seed separation in a vertical air stream.
2. Better development of embryo in beechnuts (meaning higher viability class) results in higher critical velocity and in lower variability.
3. Critical velocity allows for effective division of beech seeds into weight fractions, but without taking into account seeds with largest mass.
4. Research stand for measuring aerodynamic properties of seeds along with the developed in this work algorithm of image analysis allows for automation of the measurements while maintaining their accuracy and for visualization of the behavior of seeds in the air stream.

REFERENCES

1. Grochowicz J. 1994. Maszyny do czyszczenia i sortowania nasion. [Machines for cleaning and sorting seeds]. Wydawnictwo Akademii Rolniczej w Lublinie [in Polish].
2. Matras J. 2000. Selekcyjna i gospodarcza baza nasienna buka zwyczajnego (Fagus sylvatica L.) w Polsce. [Selective and industrial seed basis of the European beech (*Fagus silvatica* L.) in Poland]. Zeszyty Naukowe AR w Krakowie, ser. Sesja Naukowa nr 69, 103-120 [in Polish].
3. Omobuwajo T.O., Akande E.A., Sanni L.A. 1999: Selected physical, mechanical and aerodynamic properties of African breadfruit (*Treculia africana*) seeds. Journal of Food Engineering nr 40, 241-244.
4. Rigney M. P., Kranzler G. A. 1997. Machine vision for conifer seedling quality control. New Forest 13, 51-62.
5. Sabor J. 2000. Wartość genetyczna buka karpackiego. [Genetic value of Carpathian beech]. Zeszyty Naukowe AR w Krakowie, ser. Sesja Naukowa nr 69, 139-152 [in Polish].
6. Simak M. 1980. X-radiography in research and testing of forest tree seeds. Rep. 3, Department of Silviculture, Swedish University of Agricultural Science, Umea, 34 pp.
7. Suszka B., Muller C., Bonnet-Masimbert M. 1994. Nasiona leśnych drzew liściastych. [Seeds of deciduous forest trees]. Wydawnictwo Naukowe PWN, Warszawa-Poznań [in Polish].
8. Toka K. 2000. Ochrona zasobów genowych buka w Leśnym Banku Genów w Kostrzycy. [The protection of beech genetic resources in experiments of Forest Gene Bank Kostrzyca]. Zeszyty Naukowe AR w Krakowie, ser. Sesja Naukowa nr 69, 213-227 [in Polish].
9. Tylek P. 1999: Problemy selekcji pneumatycznej nasion drzew leśnych. [Problems of pneumatic selection of the forest tree seeds]. Sylwan nr 12, 65-72.
10. Tylek P. 2002: Wykorzystanie gęstości w procesie separacji orzeszków buka. [Utilization of density in the process of separation of beechnuts]. Mat. Konf. Logistics of wood technical production in the Carpathian Mountains, Technická Univerzita vo Zvolene, 276–280.
11. Tylek P., Walczyk J. 2002: Separator pneumatyczny do nasion drzew leśnych. [Pneumatic separator for forest tree sedes]. Przegląd Techniki Rolniczej i Leśnej nr 10, 16 – 25.
12. Tylek P., Walczyk J. 2002: The relationship between the viability and geometric characteristics of beechnuts (*Fagus silvatica* L.). Electronic Journal of Polish Agricultural Universities, Series Forestry Volume 5, Issue 2.

13. Wojnar L., Majorek M. 1994. Komputerowa analiza obrazu. [Computer image analysis]. Fotobit Design [in Polish].
14. Zasady oceny nasion w lasach państwowych. [Rules of seed evaluation in the State Forests], 1996. Dyrekcja Generalna Lasów Państwowych, Instytut Badawczy Leśnictwa, Warszawa [in Polish]

*The paper was supported by the State Research Committee, grant 5 P06H 077 19: "Analysis of the sorting criteria for forest tree seeds"

Paweł Tylek, Józef Walczyk
Department of Forest Works Mechanisation
Agriculture University in Cracow
29-Listopada 46, 31-425 Cracow
phone: +4812 6625023
e-mail: rltylek@cyf-kr.edu.pl
