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PHYSICAL PROPERTIES OF BARLEY SEED (*Hordeum sativum L.)* AND RESISTANCE TO BREAKAGE
FIZIČKE OSOBINE SEMENA JEČMA *(Hordeum sativum L.)* I OTPORNOST NA LOM

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ABSTARCT

The paper presents laboratory research of basic physical properties of barley seed which determine parameters vital for seed handling in harvest, primary and final processing, as well as in sowing. The study was focused on the breakage force and deformation of barley seed. The test were conducted on two varieties of winter barley: Novosadski 525 and Nonius.

The significant differences in seed properties, which are the subject of this research, pertain to the following: shape and dimensions, roundness, volume, single seed surface area, moisture, bulk density and self-density, 1000 seed mass, and dependence of compression strength on the force.

***Key words**: seed, barley, physical properties, breakage.*

REZIME

Cilj i zadatak istraživanja su ispitivanja osnovnih fizičkih osobina semena ječma, koje definišu osnovne parametre semena neophodne za manipulaciju sa semenom od momenta žetve do setve, odnosno osobine o kojim se vodi računa u toku žetve, primarne i finalne dorade kao i u toku setve. Ispitivanjem se daje akcenat na silu i deformaciju loma zrna ječma. Materijal koji je korišćen za ispitivanje su: dvoredi pivski Novosadski 525 i višeredni stočni Nonius. Predmet ovog istraživanja su sledeće fizičke osobine: oblik i dimenzije, sferičnost, zapremina, površina pojedinačnog zrna, vlažnost, nasipna gustina i sopstvena gustina, masa 1000 semena i zavisnost pritisne čvrstoće od sile. Vrednost dimenzije A kao najduže dimenzije semena za ove dve sorte kreće se oko vrednosti 7,4 mm.Vrednost dimenzija B i C kao kratkih osa elipse kreće se oko vrednosti 2,7 mm odnosno 1,9 mm, sa jako malim vrednostima standardne devijacije od 0,03 do 0,1. Otpornost na lom kao bitna osobina semena, kod ječma je ispitana pri vlažnosti 11,8%, 8,7% i 7,9%. za Novosadski 525 i pri 8,1% odnosno pri 8,6% i 13,1% za sortu Nonius. Upoređenjima funkcionalne zavisnosti sile loma i veličine deformacije od vlažnosti zrna uočvaju se razlike za dve ispitane sorte, što se može pripisati morfološkim razlikama.

***Ključne reči**: seme, ječam, fizičke osobine, lom.*

INTRODUCTION

Barley *(Hordeum sativum L.)* is important due to variety of applications. Barley bread is of lower quality, but for human diet barley is used in other forms. It is very important in the beer and malt industry. Barley has two main centers of origin, East-Asian and Abyssinian center) and Front-Asian center. Present barley varieties, widespread in industrial production, feature large fertility potential, and under proper and intensive growing technology can achieve higher yields than wheat, especially in particular micro-regions. In our country there are substantial potentials for the production of beer barley. Depending on the biological potential, relatively high barley yields are achieved. In production of beer barley, varieties of two-row barley with protein content up to 12% are used (*Jevtić,1992*).

According to data of Statistical Office of the Republic of Serbia, in the previous years, the areas under winter cereals have equaled approximately 150.000 ha, which is 15% of the total sown areas in Vojvodina. In the period from 2003 to 2008, the average harvested area of barley equaled 47,137 ha with the average yield of 3,442 kg. Serbia is ranked low in the world barley production. However, here exist natural and other conditions for substantial increase of barley production, which would satisfy requirements of livestock feed, food and feed industries (*Jevtić,1992*).

For reasons stated above, the goal of this study is to investigate the basic physical properties of barley seed, which determine parameters vital for seed manipulation in harvest, primary- and final processing, as well as in sowing. Investigation is focused on the breakage force and deformation of barley seed. The results of tests and measurements will be processed using standard statistical methods.

MATERIAL AND METHOD

In order to achieve the goal, it was necessary to carefully select the best varieties from the new seed selection. All barley samples are representative of the Vojvodina region and were prepared according to domestic norms on seed quality as provided by the *Regulation of agricultural plants seed quality: Official gazette SFRJ 47/1987*. An average seed sample must contain at least 25.000 of seeds. An average sample is packed into a clean, dry, and previously unused PVC bag which is tightly sealed. The sample is then packed into a paper bag which is labeled with information on plant species, variety designation, and seed moisture at the moment of sampling, which was measured using a portable, manual moisture meter. The samples are stored in a sample storage space where the environmental parameters and sanitary conditions are monitored and controlled (temperature 18±2ºC). The seeds used in this study are: *Novosadski 525* - two-row beer barley, and *Nonius* - multi-row fodder barley.

The winter two-row beer barley, *Novosadski 525,* belongs to the group of medium-early varieties. It is very resistant to laying down, and is moderately resistant to pre-harvest sprouting. It features high yield potential and intensive grain filling. The 1000 seed mass is approximately 42 g. Protein content ranges from 10

to 11.5%. It is exquisitely well suited for production of beer barley.

Nonius, a medium-early barley variety, resistant to low temperatures, laying down, and diseases. Protein content is over 13%, 1000 seed mass is 47g. The variety is used exclusively for livestock fodder and is recommended for growing on all types of soil.

The laboratory test involve the methods for measuring of physical and mechanical properties of seed sampled by the Laboratory for Seed Quality Testing of the Novi Sad Agricultural Station, and the Laboratory for processing equipment, of the Department for Agricultural Engineering, Faculty of Agriculture, University of Novi Sad (*Regulation of agricultural plants seed quality: Official gazette SFRJ 47/1987)*.

Seed post-processing in field crops requires application of various technological procedures which are performed based on differences in physical properties. Significant differences in seed properties which are the subject of this investigation pertain to following: shape and dimensions, roundness, volume, single seed surface area, moisture, bulk density, and self-density, 1000 seed mass, and dependence of compression strength on the force.

Shape and dimensions

Shape and dimensions are inseparable properties of a physical object and are necessary for its description *(Babić et al., 2000; Tarka and Babić, 1998)*. All agricultural products have irregular shapes. The shape of a single seed of maize, soybean, sunflower, wheat, and barley is irregular, i.e. does not assume the shape of any regular geometry body such as: cube, cuboid, sphere, pyramid, cone or cylinder. Therefore, the descriptive definition of shape is most often used, including, for example *(Mohsenin, 1980)*:

- round-like shape – shape similar to a ball,
- round-like, oblate shape,
- oblong shape – vertical diameter larger than the horizontal
- conical shape,
- egg-like shape – with sharply accented top,
- inverted egg-like shape, with sharply accented bottom,
- elliptical shape,
- truncated elliptical shape,
- uneven shape – one half larger than the other,
- corrugated shape – angular cross-section.

The dimension is derived by measurement, using caliper according to the method. In this investigation, following dimension were measured: a - length, b – width, and c – thickness, which were measured in mutually orthogonal directions *(Babić et al., 1992)*.

Roundness

Defining and measuring seed roundness is one of the ways to compare the shape of a seed to a small ball *(Mohsenin, 1980; Babić, Ljiljana and Babić, M., 2000)*. Roundness 'S' is determined as the ratio between diameters, according to (1):

$$S = \frac{d_i}{d_c} \tag{1}$$

where: d_i – diameter of an inscribed ball, and d_c – diameter of a circumscribed ball.

Volume

Volume of an irregular geometric body is most often measured by volumetric, mass or piknometer method *(Mohsenin, 1980)* or is determined using regression analysis based on three measured parameters. The volume of a single seed is calculated from (2):

$$V = \frac{a\,b\,c\,\pi}{6} \tag{2}$$

Single seed surface area

Knowledge of surface area of particular agricultural materials is of importance to geneticists, farmers, and agricultural engineers. This parameter represents the ratio between the total surface area and volume of an agricultural product defined with respect to either mass or volume unit. For every sample, calculation can be made using (3) based on previously measured surface area and volume *(Babić, Ljiljana and Babić, M., 2000)*.

$$P = (a\,b\,c)^{2/3}\ \pi \tag{3}$$

Moisture

Depending on the state of matter, moisture can be found in solid, liquid, and gaseous state. If one assumes that a material consists of moist and dry matter, then the ratio between the moist mass share, and the total mass is called moisture *(Babić, Ljiljana and Babić, M., 2000, Pivnički et al., 2003.)*.

Moisture of barley seed can vary during the time of harvest, but equilibrium moisture content is 14.0% according to the *Regulation of agricultural plants seed quality: Official gazette SFRJ 47/1987*. This physical parameter will be kept constant during this study.

Moisture of barley seed was measured in a seed dryer (Lenton, UK) at 130°C, 1h in two repetitions. Measurements were performed using analytical scale (TB 215D, Denver Instrument, Germany) with accuracy of 0,001g.

1000 seed mass

The mass of 1000 seeds of a particular cultivar depends solely on seed humidity. The mass increases with the increase of humidity. Seed mass was counted on an automatic seed counter (Pfeufer, Germany), while weightings were performed on a digital scale (Tehtnica ET 1111, Železnik, Slovenia) with a 0.01g accuracy.

Bulk and truth density

Bulk density (4) and truth density of seed is defined as the ratio between the mass and total volume (the sum of sheer seed volume and interspace), while the truth density (*Mohsenin, 1980*) is the ratio between seed mass and sheer seed volume, interspace excluded. Both parameters depend on seed shape and moisture, as well as the pile height.

$$\rho = \frac{m}{V}\quad \left(kg/m^3\right), \tag{4}$$

$$\rho_s = \frac{m}{V_p}\quad \left(kg/m^3\right), \tag{5}$$

where: m - seed mass (kg), V – total volume of product and interspace (m^3), V_p - volume of product only (m^3).

Dependence of compression strength on the force (resistance to breakage)

The seeds of investigated agricultural plant species are not only of various shapes, but also structure, and therefore differently react under impact of some external force, which can result in plastic deformation or seed breakage. Based on the so far research *(Gupta et al., 2000)* a relatively small compression force

13.4-8.5 N is sufficient to permanently damage the seeds. *(Praveen et al., 1995; Babić Ljiljana et al., 2001; Babić M. et al., 2000)* also confirmed that with the increase of seed moisture, the force magnitude which causes permanent damage is lower.

Investigation of compression load was performed with both barley varieties. For each test, the sample size was 15 seeds. Three levels of seed moisture were selected for each of the two varieties. For *NS 525* the moisture values were 7.9%, 8.7% , and 11.8%, while for *Nonius* they equaled 8.1%, 8.6%, and 13.1% respectively.

The instrument used for the measurement consists of a compression cell, and a dedicated software (*Food Technology Corporation, model TMS-PRO*). The compression cell provided forces in the range of 0.5 to 500 N. Compression head velocity prior to contact with the sample was 60 mm/min, while the contact velocity was 30 mm/min.

Each individual seed was placed suture-down on the lower plate, i.e. it was in contact with the plate.

RESULTS AND DISCUSSION

The results of three seed dimensions are presented in table 1.

Table 1. Basic dimensions of barley seed

	Novosadski 525			Nonius		
	a(mm)	b(mm)	c(mm)	a(mm)	b(mm)	c(mm)
$\overline{X}$	7.48	2.77	1.96	7.39	2.65	1.87
σ	0.65	0.32	0.18	0.54	0.20	0.21
V	0.42	0.10	0.03	0.33	0.04	0.04
$T_{calc.}$	0.979607	3.221397	3.34503	0.979607	3.221397	3.34503

Value of dimension *a*, as the largest dimension for the two varieties, equals 7.4 mm with standard deviations of 0.42, and 0.33, respectively. Values of B and C as the minor axes of ellipse are 2.7 mm, and 1.9 mm, respectively, with very small standard deviations, from 0.03 to 0.1. Based on *t-test* for the mean sample values, one concludes that there is no significant difference at 95 and 99 % alpha levels for dimension A. In other words, varieties *Novosadski 525* and *Nonius* have the same seed length. However, the *t-test* for dimensions B and C showed significant difference at 95 and 99 % alpha levels. Therefore, the conclusion is that a difference exists in these dimensions for the two varieties, which is attributed to their inherent properties.

Table 2. Equivalent diameter, surface area, volume, and roundness of barley seed

	Novosadski 525				Nonius			
	$d_{eqv.}$ (mm)	P (mm^2)	V (mm^3)	Sphericity	$d_{eqv.}$ (mm)	P (mm^2)	V (mm^3)	Sphericity
$\overline{X}$	3.43	37.26	21.58	0.46	3.31	34.65	19.30	0.45
σ	0.27	5.78	5.04	0.03	0.22	4.57	3.76	0.03
V	0.07	33.42	25.38	0.00	0.05	20.90	14.16	0.00

The tabular T value at 0.01 equals 2.756386, while *t* tabular at 0.05 equals 2.04523.

Mean value of equivalent seed diameter for *Novosadski 525* variety is 3.43 with a 0.27 standard deviation, while for the *Nonius* variety this value equals 3.31 with a 0.22 standard deviation. Based on t-test, there is no significant difference at alpha 95 and 99 %, since the calculated value of *t* is 1.876872, which is less than the tabular *t* value.

Mean value of seed surface area for *Novosadski 525* variety is 37.26 with a 5.78 standard deviation, while for *Nonius* it equals 34.65 with a 4.57 standard deviation. Based on *t*-test there is no significant difference at α 95% and 99 %, since the calculated *t* is 1.909675, which is less than tabular *t* value.

Mean value of seed volume for *Novosadski 525* variety is 21.58 with a 5.04 standard deviation, while for *Nonius* this value equals 19.30 with a 3.76 standard deviation. Based on *t*-test there is no significant difference at alpha 95 and 99 %, since the calculated *t* is 1.938833, which is less than tabular *t* value.

Mean value of seed roundness for *Novosadski 525* variety is 0.46 with a 0.03 standard deviation, while for the *Nonius* it equals 0.45 with a 0.03 standard deviation. Based on *t* test there is no significant difference at alpha 95 and 99 %, since the calculated *t* is 1.837029, which is less than the tabular *t* value.

The values of moisture content for Novosadski 525 and Nonius are 13.2% and 13.9% (Tab. 3) were determined based on the measurements defined in the section material and method, while the bulk- and true density were calculated from equations 4 and 5. There is a notable difference between the bulk- and self density in both barley varieties: 691.23 and 1158.61, i.e. 643.08 and 1064.43 kg/$m^{3,}$ respectively. The 1000 seed mass equals 215.88, that is 218.5 g.

Table 3. Moisture, bulk density, self-density of barley and 1000 seed mass

	Novosadski 525				Nonius			
	W (%)	ρ (kg/m^3)	ρ_s (kg/m^3)	M 1000 seed (g)	W (%)	ρ (kg/m^3)	ρ_s (kg/m^3)	M 1000 seed (g)
$\overline{X}$	13.2	691.23	1158.61	215.88	13.9	643.08	1064.43	218.50

Values for the two varieties of moisture content, bulk density and self-density, as well as 1000 seed mass, do not show statistically significant difference.

Resistance to breakage as an important barley seed property, was tested at 11.8%, 8.7% and 7.9% moisture for *Novosadski 525*, and at 8.1%, 8.6% and 13.1% moisture for *Nonius* variety.

Fig. 1 illustrates functional dependence between the rapture force and seed moisture content, while Fig. 2 shows dependence of the displacement and moisture content at a constant breakage force value. As shown in Fig.1, there are differences between the two varieties, which can be attributed to different chemical compositions of seeds. Similar can be concluded regarding the dependence between the deformation magnitude and moisture content. These two parameters are key indicators of the difference between the two varieties.

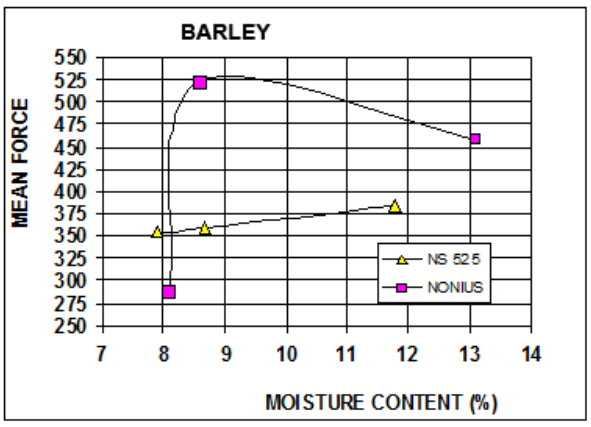

Fig. 1. Dependence of rapture force on seed moisture content

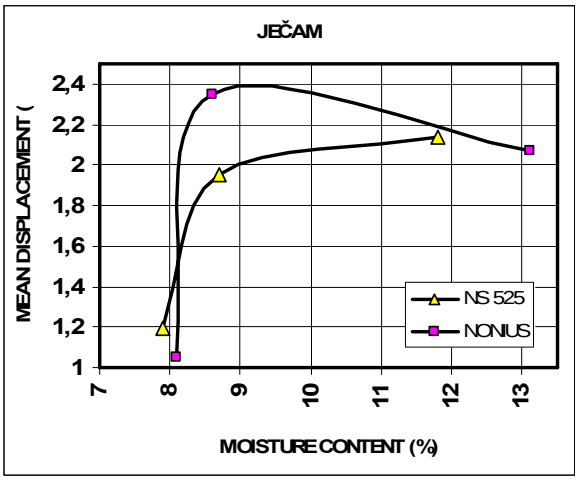

Fig. 2. Dependence of displacement and seeds moisture content

CONCLUSION

Physical properties of two barley varieties *Novosadski 525.* and *Nonius*, were analyzed using standard statistical methods to compare two samples. The conclusion is that they did not show any significant difference in basic dimensions: width, thickness, seed surface area, seed mass, equivalent diameter, and roundness, with the length being the only dimension which showed statistically significant difference at 95 and 99% alpha levels (*t-test*).

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