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COMPARISON OF STRENGTH FEATURES OF RAPE PODS AND SEEDS FOR VARIETIES CULTIVATED IN VARIOUS COUNTRIES*

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A b s t r a c t. A big step toward better varieties of rape took place in the last twenty years in countries which have a high production of this plant. This genetic progress results in better quality of raw material for oil production and a higher amount of oil obtained per unit of cultivation area.

However, with the improvements of some genetic features, others became worse. Reducing the amount of glucosinolates and eruic acid as well as increasing yield was the main object of genetic improvements of rape; however at the same time strength of pods and seeds decreased.

The aim of the present studies was to compare strength features of pods and seeds of some rape varieties cultivated in various countries. Mechanical properties of pods were checked according to the method elaborated in the Institute of Agrophysics of the Polish Academy of Sciences. Basic mechanical parameters derived from torsion tests of single pods were compared in order to estimate varietal cracking resistance. Mechanical strength of seeds was determined using quasi-static compression test. Damaging force and deformation, energy and modulus of elasticity were chosen as characteristic parameters obtained from this test. Variability of strength features of pods and seeds was determined. Varieties were evaluated according to technological value.

K e y w o r d s: rape pods, rape seeds, strength features

INTRODUCTION

Countries of high rapeseed production compete in high yield as well as quality of this plant, improving its genetic features. However, yield potential is only one of the factors which have an influence on the amount of harvested seeds. Investigations carried out by the Institute of Agrophysics in Lublin showed that up to 10 % of the total yield could be lost before and during harvesting. This is in agreement with rape breeders' observations. Various factors influence the extent of losses, but of basic importance are the strength features of pods.

The coherence of a pod's suture is one of a varietal features which determine the crack resistance of a variety.

During harvesting and postharvest handling seeds underwent loads of various character, resulting in kernel damage. Resistance to mechanical damage depends on a number of factors, but variety features seem to be very important.

The aim of the present studies was to compare rapeseed varieties from various countries. A comparison according to strength of pods and seeds was made; analysis of variance proved the differentiation of mechanical parameters of tested varieties.

MATERIAL AND METHOD

The four varieties of rape were considered:
- Bolko - variety bread in Poland,

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- Westar - variety of Canadian origin,
- Ceres - German variety,
- Jet Neuf - variety from France,
- Jupiter - Swedish variety.

Bolko is one of the basic double zero Polish varieties developed in 1989. Material of Bolko came from field experiments of the Institute of Agrophysics. Westar is a Canola type spring variety developed in 1982. Pods and seeds of this variety came from the experimental farm of Saskatchewan University, Canada. Ceres, developed in 1988 in West Germany, is very popular in Poland and material for the investigation came from field experiments of the Institute of Agrophysics. Material of var. Jet Neuf, a low-eruic variety developed in France, was also collected from field experiments of the Institute of Agrophysics. Jupiter was obtained from Sweden (Swölöf Research Station) and this is a winter rape double zero type.

Method of investigation of pod strength

Strength features of pods were examined in torsion test (Fig. 1). A single pod was fastened in a special handle with two jaws. One jaw was immovable and the second was rotative and fixed with a wheel. An elastic cord reeled on the wheel facilitated measuring the torque of the turning pod. The cord was fasten to the measuring head, which feed up gave a torsion of pod. An analogue signal from the head was registered with a computer as a curve in torque and turning angle coordinate system (Fig. 2). A turning angle of 180^o induced a total crash of the sutures. Each test consisted of two torsions:

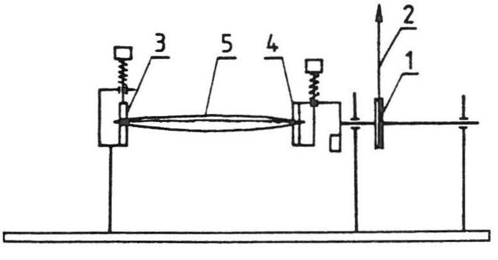

Fig. 1. Scheme of pod fixed in torsion handle: 1 - wheel, 2 - cord, 3 - immovable jaw, 4 - rotation jaw, 5 - pod.

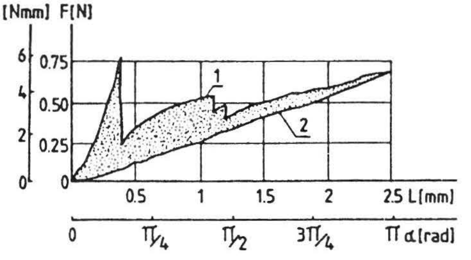

Fig. 2. Torsion curve of the pod: 1 - curve obtained in first torsion (intact pod), 2 - curve obtained in second torsion of the same pod, M_s - torque, F - registered force, α- torsion angle, L - calculated linear deformation.

- first to evaluate physical parameters of an intact pod (curve 1),
- second to evaluate torsion energy of the same pod with broken sutures (curve 2).

Seven parameters characterizing pod strength were evaluated during the test:

1. A - total torsion energy of a pod with unbroken sutures,
2. A' - energy of torsion of a pod with broken sutures,
3. A'' - energy causing the first crack of satures,
4. ΔA - energy represents coherence of the sutures,
5. M_{max} - maximal torque
6. α- angle representing the first crack
7. R - summary strength coefficient.

Summary strength coefficient R was calculated on the basis of previously obtained parameters, according to the formula:

$$R = -0.42 + 0.21A' + 1.64A'' + 0.38\,\Delta A + 0.30M_{max} + 2.91\,\alpha . \quad (1)$$

Material for investigating pod's strength

Pods were collected during full maturity of plants and came from plants grown inside the field (at least 0.5 m from the edge). From 3 to 9 pods were taken from different parts of individual plants. Three parts chosen were:

- lower with side-branches,
- middle with side-branches,
- upper - from main shoot.

Pods were cut with a secateur, and the peduncle was left as long as possible in order to not injure the sutures. Only straight, unbroken and health pods with equalized maturity were taken for the investigation, and the minimal length of each pod was 60 mm. Pods were conditioned in a store room before testing in order to equalize their moisture content. 50 pods from every variety were tested.

Method of investigation of seed strength

Compression test of a single seed was chosen to evaluate its strength features. Every seed was placed with horizontal dividing plain of cotyledons and individualy compressed between two parallel plates fixed into an INSTRON testing machine model 6022. Deformation velocity was 10 mm/min. Signal from the machine was registered with the personal computer, connected to the INSTRON through analog-digital converter. Curve in force-deformation coordinate system was obtained (Fig. 3). The following parameters were derived from the curve:

- maximal compression force (F_{max}),
- deformation corresponding to the maximal force (d_{max}),
- force causing the first indivertible change (first rupture) (F_e),
- deformation corresponding to this force (d_e),
- energy required to totally damage the seed,
- apparent modulus of elasticity.

The force causing the first indivertible change and the deformation corresponding to it were considered as the limits of elasticity. These limits were stated at the point where compression curve showed unlinearity (deviated from the initial linear part) and were obtained by drawing tangential to the linear part of the curve.

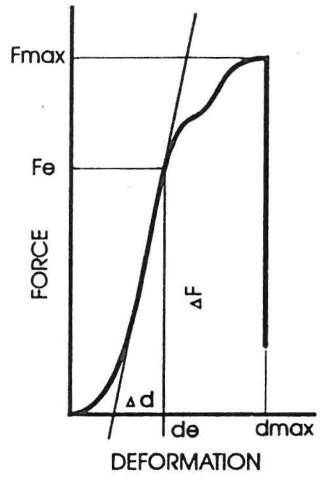

Fig. 3. Typical compression curve of a single seed with a scheme of modulus of elasticity calculation.

Apparent modulus of elasticity was calculated from the linear part of the curve, according to Hertz' theory:

$$E = \frac{1.061(1-\mu^2)}{\pi}\left(\frac{K^3}{R}\right)^{1/2}\left(\frac{(\Delta F)^2}{(\Delta d)^3}\right)^{1/2} \quad (2)$$

where μ - Poisson's ratio, K - constant, R - radius of seed curvature, F - force in the linear part of compression curve, d - deformation of the seed. Poisson's ratio was assumed as 0.4 and constant K as equal 1.3514.

Material for investigating seed's strength

Seeds came from the same field experiment as the pods. They were collected at full maturity, threshed by hand and dried in the open air in order to avoid initial damage. Moisture content of the seeds was 7 % w.b. during the tests. Seeds were separated on sieves in order to obtain kernels with the same dimensions. Only those kernels which did not come through the sieve with 2 mm holes, but stood in holes of this sieve were taken for the investigation. 50 seeds of each variety were compressed.

RESULTS

Strength of pods

Both strength coefficient and other parameters showed considerable differences according to rape variety.

First parameter A - total torsion energy of an unbroken pod (Fig. 4a), differed from 6.2 mJ for Bolko to 18.1 mJ for Westar. Total torsion energy for Ceres 6.3 mJ was slight more than for Bolko and had similar confidence intervals. Jet Neuf had 4.7 mJ and Jupiter 5.6 mJ total torsion energy. It is easy to notice that this parameter is comprised of three partitions: lower (Bolko and Ceres), middle (Jet Neuf and Jupiter) and higher (Westar). The difference between the first and second partitions was much less than between the second and third, showing that pods, including sutures, of Westar were much more resistant to torsion, than pods of other varieties.

The second parameter A' - energy of a pod with broken sutures showed the resistance to torsion of pods broken into two parts (Fig. 4b). This parameter was the largest

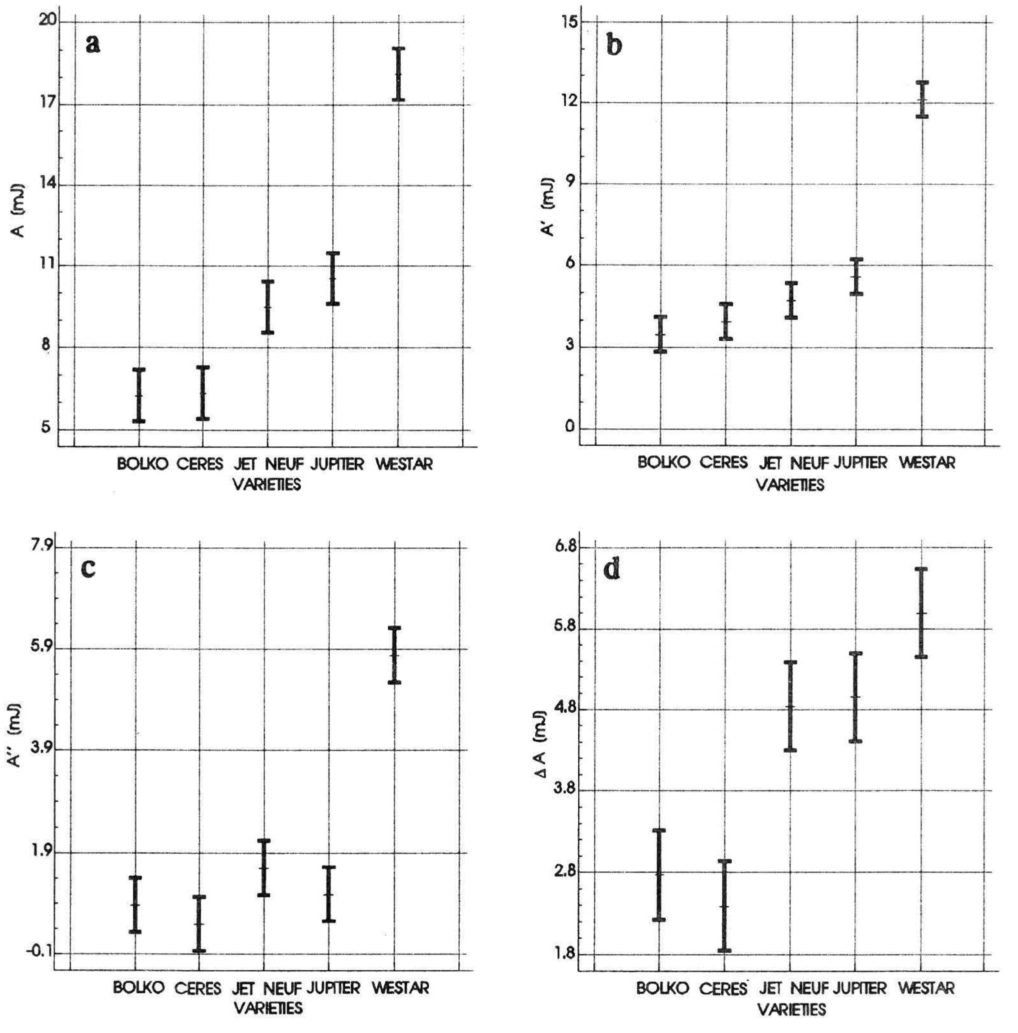

Fig. 4. Means and confidence intervals of parameter A (a), parameter A' (b), parameter A'' (c) and parameter ΔA (d).

for Westar (12.1 mJ), but for other varieties differed slightly (from 3.5 mJ for Bolko to 5.6 for Jupiter).

The next parameter showed energy reqiured to the first crack of pod's sutures (Fig. 4c). This energy was similar for Bolko, Ceres, Jet Neuf and Jupiter (0.49 mJ to 1.61 mJ) with insignificant differences, while for Westar this energy reached 5.77 mJ, about four times more than for the other varieties.

The difference between total torsion energy of a pod A and energy of pod with broken sutures A' was calculated and expressed as ΔA. This parameter represented coherence of the suture (Fig. 4d). Westar had the strongest suture, Jupiter and Jet Neuf had slightly weaker sutures, and Bolko and Ceres had the weakest sutures. ΔA differed from 5.99 mJ for Westar to 2.39 mJ for Ceres.

Maximal torque (Fig. 5a) reached the biggest values for Westar and the lowest for Ceres, similarly to a value of angle of the first crack (Fig. 5b). Maximal torque for Westar was 9.6 Nmm and for Ceres 2.9 Nmm with other varieties between 3.9 Nmm to 5.4 Nmm. The angle of first crack was 1.16 rad for Westar and 0.34 rad for Ceres; Ceres pods cracked four time earlier than pods of Westar. The difference between for Bolko, Ceres, Jet Neuf and Jupiter was insignificant.

The strength coefficient R calculated from the above mentioned parameters was the highest 20.6 for Westar variety and differed significantly from the coefficient of other varieties (Fig. 6). Among Bolko, Ceres, Jet Neuf and Jupiter coefficient R did not differ significantly and was equal to 4.8 on the average.

Strength of seeds

Parameters derived from compression tests of individual seeds of each variety showed differentiation of mean values as well as size of confidence intervals.

First parameter - elastic force (Fig. 7a), showed that Westar was significantly different from the other varieties, except for Jet Neuf, where the average elasticity force was 9.22 N with a relatively big confidence interval. The highest mean had Ceres - 10.1 N with relatively small confidence interval.

The deformation corresponding to the elastic force (Fig. 7b) was the highest for Bolko (0.23 mm) and the lowest for Jet Neuf and Jupiter both 0.17 mm. Bolko differed significant from Jet Neuf and Jupiter,

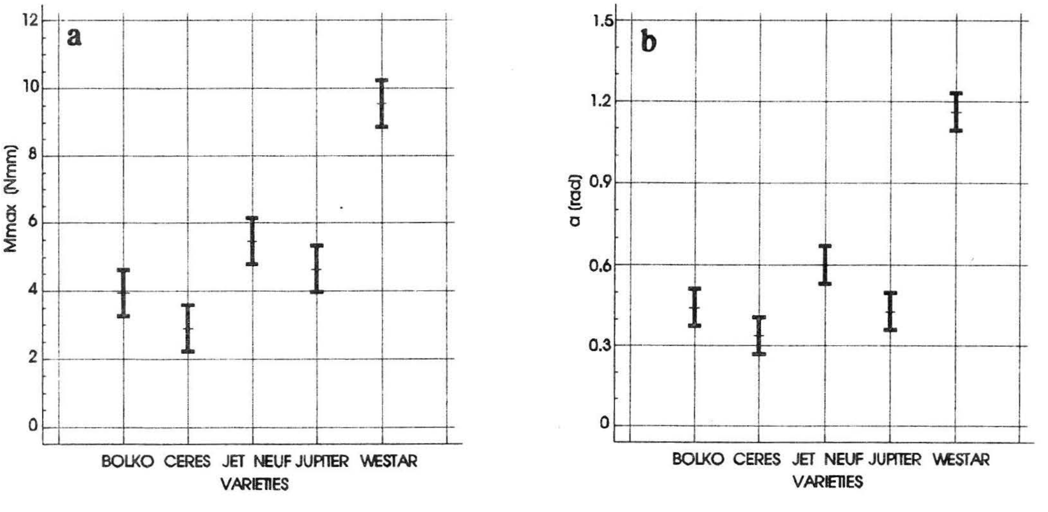

Fig. 5. Means and confidence intervals of parameter M_{max} (a) and parameter α (b).

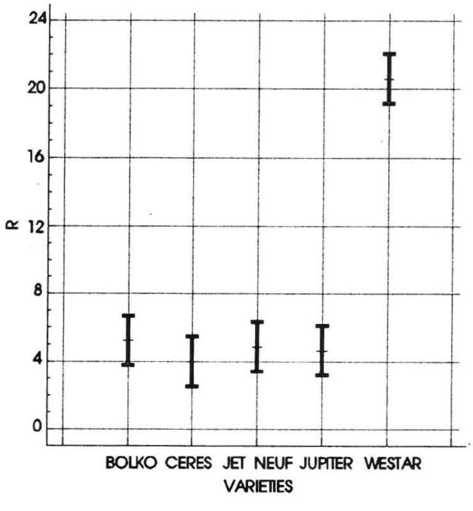

Fig. 6. Means and confidence intervals of parameter R.

according to this parameter. Ceres and Westar had the smallest confidence intervals.

Next parameter, maximal force causing damage to a seed cover (Fig. 7c) was the biggest for Ceres (17.79 N) and the smallest for Westar (11.36 N). These varieties had the smallest confidence intervals. Significant differences occurred between Westar and Jupiter, Ceres, Bolko, likewise between Jet Neuf and Ceres, Bolko.

The deformation causing cover damage (Fig. 7d) was the smallest (0.24 mm) for both Jet Neuf and Jupiter, while for Bolko this deformation reached 0.37 mm.

The energy required for seed damage (Fig. 8) reached 2.77 mJ for Bolko and Ceres, while for Jet Neuf it was 1.58 mJ. Values of this parameter were divided into two groups: higher - Bolko and Ceres and lower - Westar, Jupiter and Jet Neuf. The differences between these groups were statistically significant.

Apparent modulus of elasticity of seeds (Fig. 9) varied from 29.2 MPa for Bolko to 50.11 MPa for Jupiter. Confidence intervals of this parameter were smaller for Ceres and Westar while for Bolko, Jet Neuf and Jupiter they were bigger.

DISCUSSION

Strength features of pods and seeds could be, in addition to chemical composition, yield, etc., one of the most important factors concerning rape cultivation. The selection of varieties could be made toward more resistance to shattering and mechanical damage of seeds. This could benefit in quantity and quality of yield.

Comparing studied varieties, Canadian variety Westar characterized high pod resistance to torsion and relatively low seed resistance to compression. All measured pod parameters were greater for Westar than for the other varieties, resulting in a summary strength coefficient R nearly four times bigger. It should be stated that the material and shape of pods played a main part in this result (see parameter A and A'), but the sutures were relatively not so strong (see parameter ΔA). Excellent pod characteristics predict good crack resistance of this variety; however, mechanical parameters of the seeds were poor. Relatively light loads caused failures and damage, although Westar seeds could deform more than, for example, Jupiter or Jet Neuf.

Pods of the Polish variety Bolko were not as stiff as pods of Westar, but their total strength expressed in coefficient R had second value among the studied varieties. The same situation was noticed for the rest of the varieties, although their summary strength coefficients did not differ significantly. The high coherence of sutures of Jet Neuf and Jupiter should be stressed (see parameter ΔA). Nevertheless, this did not reflect in the coefficient R of these varieties. Jupiter had the biggest modulus of elasticity of seeds. Seeds of this variety withstood relatively high loads with little deformation (elastic and maximal), but the energy required to damage was very small.

The German variety Ceres characterized the worst pod features of all varieties tested: the smallest energies A'' and ΔA as well as the smallest torque M_{max} at the little angle resulted in the smallest summary

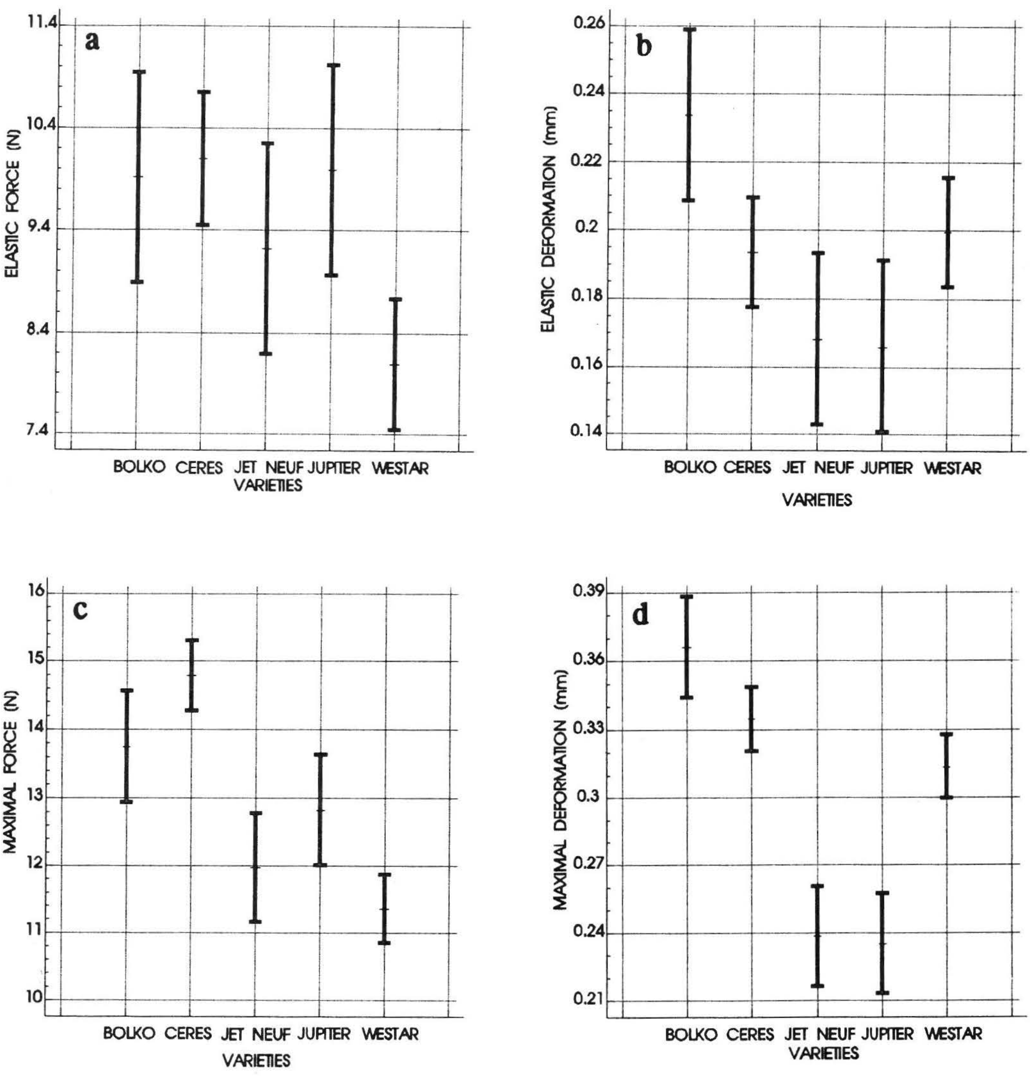

Fig. 7. Means and confidence intervals of compression elastic force (a), elastic deformation (b), maximal force (c) and maximal deformation (d).

coefficient *R*. Nevertheless, seeds of this variety withstood high loads and deformations, both maximal and elastic. They also needed a large amount of energy to damage (similar like Bolko) and had a large apparent modulus of elasticity.

Evaluating the technological value of each variety, it should be stated that a high crack resistance of pods did not correlate with high damage resistance of seeds. The best pods characteristic of Westar guarantee low shattering losses; however, the poor strength features of Westar seeds could cause high quality losses. Contrariwise, Bolko could give seeds of better quality but shattering losses could be greater, assuming similar growing and harvesting conditions.

CONCLUSIONS

1. Methods used in the investigation proved their usefulness for evaluating the technological value of various varieties.

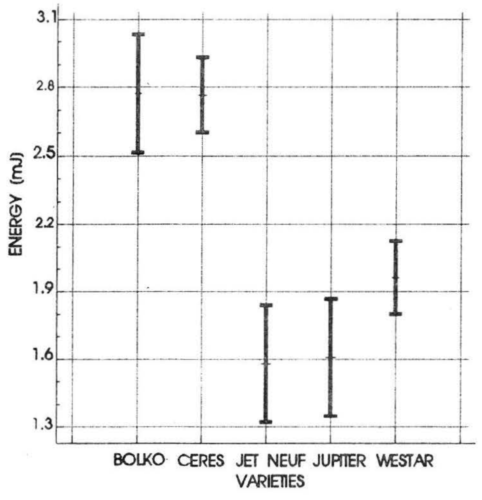

Fig. 8. Means and confidence intervals of seed damaging energy.

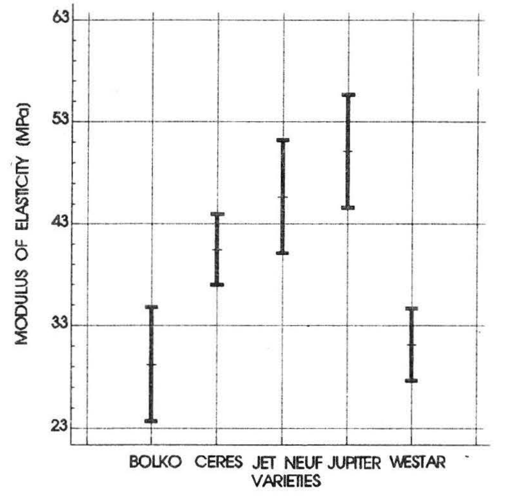

Fig. 9. Means and confidence intervals of seed modulus of elasticity.

They could also be used to compare new varieties before introducing to cultivation.

2. Tested varieties showed considerable variability of strength parameters of pods and seeds, but strength features of pods did not follow strength features of seeds.

3. The best crack resistance proved Canadian spring rapeseed variety Westar. Cracking differences among other varieties were not significant.

4. The Polish winter rapeseed variety Bolko had the best strength parameters of seeds, however, the apparent modulus of elasticity for this variety was relatively small.

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