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EFFECT OF WATER DEFICIT ON GAS EXCHANGE PARAMETERS, PRODUCTIVITY AND GRAIN WHOLESOMENESS OF SPRING WHEAT

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K e y w o r d s: water deficit, spring wheat, photosynthesis, transpiration, stomatal conductance, intercellular CO_2 concentration, grain wholesomeness, BIO-PCR.

A b s t r a c t

The rate of photosynthesis and transpiration, intercellular CO_2 concentration and stomatal conductance in spring wheat plants were determined in an experiment conducted during the years 2004–2005. The severity of fungal infection of wheat kernels was estimated by a traditional method and a molecular BIO-PCR technique with the use of universal and SCAR primers. It was found that water deficit decreased thousand grain weight, grain weight per plant and the values of gas exchange parameters (including photosynthesis, transpiration, stomatal conductance, intercellular CO_2 concentration), in particular photosynthesis. The values of biometric characters did not decrease. The rate of wheat grain colonization by fungal pathogens was slightly higher under water stress conditions.

WPŁYW DEFICYTU WODNEGO NA WSKAŹNIKI WYMIANY GAZOWEJ, PRODUKCYJNOŚĆ I ZDROWOTNOŚĆ ZIARNA PSZENICY JAREJ

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S ł o w a k l u c z o w e: niedobór wody, pszenica jara, fotosynteza, transpiracja, przewodność szparkowa, międzykomórkowe stężenie CO_2, zdrowotność ziarna, BIO-PCR.

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Abstrakt

W latach 2004–2005 przeprowadzono eksperyment badawczy, w którym mierzono intensywność fotosyntezy i transpiracji, międzykomórkowe stężenie CO^2 oraz przewodność szparkową pszenicy jarej. Określono ponadto zasiedlenie grzybami ziarniaków – metodą tradycyjną oraz molekularną BIO-PCR z wykorzystaniem primerów uniwersalnych oraz typu SCAR. Wykazano, że deficyt wody spowodował obniżenie MTZ, masy ziarna z rośliny oraz wskaźników wymiany gazowej (fotosynteza, transpiracja, przewodność szparkowa, międzykomórkowe stężenie CO_2), a zwłaszcza fotosyntezy. Nie stwierdzono natomiast spadku wartości cech biometrycznych. Zanotowano także nieco wyższe zasiedlenie ziarna pszenicy jarej patogenami grzybowymi w obiektach z niedoborem wody.

Introduction

One of the factors that determine the growth, development and yield of crops is adequate water supply, which is essential to all life processes. Water deficit disturbs metabolic reactions, leads to changes in the chemical composition of seeds as well as to considerable yield loss and quality deterioration (KACPERSKA 1991, GRZESIUK and GÓRECKI 1994, OZTURK and AYOLIN 2004). Water deficit is caused by a substantial water shortage in the soil, atmospheric drought, and the excess of transpiration over absorption (BOCZEK and SZLENDAK 1992, FORDOŃSKI et al. 1994). Moisture deficiency is manifested in plant wilting already when water levels decrease from 75–90% (considered optimal) to 55–70% (GRZESIUK et al. 1999). Long-term drought may damage photosystem II (PS II) structure, which in turn reduces the rate of photosynthesis. Plants respond to water stress by closing their stomata to prevent water loss, which hinders CO_2 assimilation. The adverse changes in the photosynthesis process lead to considerable yield loss. On the other hand, plants grown under water deficit conditions have an ability to alter their metabolism so as to save water and minimize the negative effects of its shortage.

Among the biotic factors affecting the photosynthesis process, an important role is played by various diseases, 80% of which are caused by fungal pathogens. At an advanced stage of a fungal disease, the rate of photosynthesis may be reduced by as much as 75%. This results, among others, from a decrease in leaf surface area caused by damage to the green organs of a plant, plant growth inhibition or the occurrence of extensive necrotic lesions. Moreover, organelle destruction in infected plants leads to disturbances in water relations.

In view of the above, a study was undertaken to determine the effect of water deficit on the morphological characters, gas exchange parameters and grain wholesomeness of spring wheat.

Materials and Methods

A two-factorial pot experiment was conducted in six replications in the greenhouse of the University of Warmia and Mazury in Olsztyn, during the years 2004–2005. The experimental factors included spring wheat cv. Nawra, and two levels of soil moisture content:
– optimal (60–70% of capillary water capacity),
– deficient (30–35% of capillary water capacity).
Scope of the study:
– determination of gas exchange parameters (the rate of photosynthesis and transpiration, stomatal conductance and intercellular CO_2 concentration), with the use of a LI-COR 6400 portable gas analyzer;
– mycological evaluation of wheat grain by a traditional method and molecular techniques (BIO-PCR, SCAR-PCR), preceded by DNA isolation;
– determination of selected biometric characters of wheat plants.

Gas exchange parameters were measured five times, at several-day intervals, using a LI-COR 6400 gas analyzer (Portable Photosynthesis System, DMP AG S.A. LTD, at a constant CO_2 concentration of 400 ppm and illumination of 1000 μmol m^{-2} s^{-1}. The source of photons was a LED Light Source lamp, emitting wide-spectrum light at a peak wavelength of between 670 nm and 465 nm. Measurements were performed on the flag leaf of spring wheat plants, at selected development stages. Mean values for each stage are given in the paper.

In order to determine the health status of spring wheat grain by a traditional method (artificial cultures), 100 kernels were selected randomly of each treatment. The kernels were rinsed under running water for 15 to 20 minutes and surface disinfected with 70% ethyl alcohol and 1% sodium hypochlorite to remove impurities, and next rinsed three times in sterile distilled water. Then the kernels were placed in Petri dishes with a PDA solid medium. The dishes were stored in a thermostat at 20 to 23°C for 7 to 10 days, and next mycelium hyphae were transferred to PDA slants. Finally fungal cultures were identified to genus and species based on their morphological characters observed under an optical microscope, as described in the monographs by ELLIS (1971), GILMAN (1957) and KWAŚNA et al. (1991).

Mycelium hyphae (i.e. live pathogen inoculum with potential infectious properties) obtained from kernels cultured on a PDA medium were isolated in separate Petri dishes for BIO-PCR analysis. After 2 to 3 days mycelium pieces were taken with a scalpel, placed in porcelain mortars and ground in liquid nitrogen. DNA was isolated by the CTAB method (NICHOLSON et al. 1996). Polymerase chain reaction (PCR) was performed using primers known from literature (PARRY and NICHOLSON 1996, HUE et al. 1999).

Experimental results were processed statistically based on a multiple range test involving mean values in homogenous groups, at a significance level of $\alpha = 0.01$, with the use of STATISTICA ver. 6.0 software.

Results and Discussion

The results of the present study, obtained both in the first and second year of the experimental period, revealed a decrease in the values of the tested biometric characters of spring wheat plants under conditions of reduced capillary water capacity, in comparison with the control treatment (Table 1). However, significant differences were observed only with respect to grain weight per plant and thousand grain weight.

Table 1
Selected biometric characters of spring wheat cv. Nawra under water stress conditions (mean values of 2004–2005)

Cultivar	Water capacity of the soil (%)	Plant height (cm)	Number of spikes per plant	Number of grains per spike	Thousand grain weight (g)	Grain weight per plant (g)
Nawra	60–70%	49.60^{A}	2.90^{A}	11.87^{A}	38.7^{B}	1.29^{B}
	30–35%	45.84^{A}	2.26^{A}	12.64^{A}	30.9^{A}	0.77^{A}

Homogeneous groups *A, AB, B* – according to Fisher's LSD test

KOCOŃ and SUŁEK (2004) also noted an average yield decline of around 30% under moisture deficiency conditions. Such a decrease results from the plant's response to water stress involving a decrease in the rate of photosynthesis and growth (LU and ZHANG 1998, STARCK 2002).

Crop yield is largely dependent on the photosynthesis process as well as on the transport and distribution of assimilates (AUSTIN et al. 1977, NALBORCZYK 1989, STARCK et al. 1995). The rate of photosynthesis may be limited by almost all adverse environmental factors (STARCK 1995). One of such factors is water shortage in the soil, related to weather conditions.

It was found that water deficit over the period from ear formation to grain filling in the tested cereal species caused a significant decrease in the rate of photosynthesis, particularly noticeable in the first year of the experiment (Table 2). As regards transpiration and intercellular CO_2 concentration, a similar response was observed later, i.e. from the flowering stage to grain filling. Stomatal conductance remained at a comparable level. In the second year the values of all parameters of gas exchange were similar, but the intensity of changes was slightly lower (Table 3).

Table 2

Gas exchange parameters in spring wheat under water stress conditions in 2004

Cultivar	Capillary water capacity	Photosynthesis (μmol $CO_2 m^{-2} s^{-1}$)			Transpiration (mmol $H_2O m^{-2} s^{-1}$)			Intercellular CO_2 concentration (μmol $CO_2 mol^{-1}$)			Stomatal conductance (mol H_2O $m^{-2} s^{-1}$)		
		I	II	III	I	II	III	I	II	III	I	II	III
Nawra	60–70%	12.5^B	9.4^B	6.3^B	3.9^A	2.2^B	1.1^B	337^A	254^B	192^B	0.33^A	0.19^A	0.08^A
	30–35%	5.8^A	7.1^A	4.9^A	3.2^A	1.3^A	0.4^A	303^A	212^A	114^A	0.20^A	0.14^A	0.05^A

I – measurement of gas exchange parameters at the ear formation stage;
II – measurement of gas exchange parameters at the flowering stage;
III – measurement of gas exchange parameters at the grain filling stage.

Table 3

Gas exchange parameters in spring wheat under water stress conditions in 2005

Cultivar	Capillary water capacity	Photosynthesis (μmol $CO_2 m^{-2} s^{-1}$)			Transpiration (mmol $H_2O m^{-2} s^{-1}$)			Intercellular CO_2 concentration (μmol $CO_2 mol^{-1}$)			Stomatal conductance (mol H_2O $m^{-2} s^{-1}$)		
		I	II	III	I	II	III	I	II	III	I	II	III
Nawra	60–70%	12.5^B	8.3^A	8.4^B	2.4^A	1.8^A	3.0^B	320^B	173^A	139^B	0.38^A	0.06^A	0.08^A
	30–35%	9.6^A	7.7^A	5.6^A	1.9^A	1.6^A	1.1^A	262^A	155^A	107^A	0.15^A	0.06^A	0.01^A

I, II, III – explanations as in Table 2.

The present results are consistent with the findings of PSZCZÓŁKOWSKA et al. (2003) who demonstrated that the rate of photosynthesis decreased in response to water shortage in the soil. A similar trend was observed by OLSZEWSKI et al. (2007) who studied the response of winter wheat to moisture deficiency. Photosynthesis, especially in the flag leaf, is particularly important during kernel formation, when bottom leaves begin to wilt (INOUE et al. 2004), because the rate of this process affects yield height.

Microscopic mycological analyses of wheat grain, performed in 2004, showed the presence of *Chaetomium* spp. only in the water-deficient treatment (Table 4). In 2005 the rate of fungal infection was substantially higher. Fungal isolates were found in both the control and water-deficient treatment. The dominant species was *Penicillium* ssp. The proportion of potentially pathogenic fungi of the genus *Fusarium* was also high. The occurrence of *Fusarium graminearum, Fusarium poae* and *Fusarium proliferatum* was confirmed. *Fusarium proliferatum* is a common species in southern Europe (Spain). OLSZEWSKI et al. (2007) reported the presence of this pathogen under greenhouse conditions, which could be related to high temperature levels during the experiment. In our study the number of fungal isolates was slightly

higher in the water-deficient treatment. According to FORDOŃSKI et al. (1994), water stress decreases plant resistance, thus contributing to increased disease incidence.

Table 4
Number of fungal isolates in spring wheat grain cv. Nawra under water stress conditions in the years 2004–2005

Fungal species	Control	Water stress
	60–70% capillary water capacity	30–35% capillary water capacity
2004		
Chaetomium spp.		1
Total		**1**
2005		
Colletotrichum graminearum		1
Fusarium gramniearum		1
Fusarium poae (Peck) Wollenw.	4	3
Fusarium proliferatum	3	3
Mucor spp.		1
Penicillium spp.	23	27
Total	**30**	**36**

60–70% capillary water capacity – control
30–35% capillary water capacity – water stress

The results of microscopic examinations were partly confirmed by BIO--PCR analyses with the use of SCAR primers (Figure 1). The PCR products indicated the presence of fungi of the genus *Fusarium*. Further analyses revealed the occurrence of *Fusarium poae* in the second year of the study (Figure 2), as indicated by a PCR product of 220 bp. Similar results were obtained by PARRY and NICHOLSON (1996).

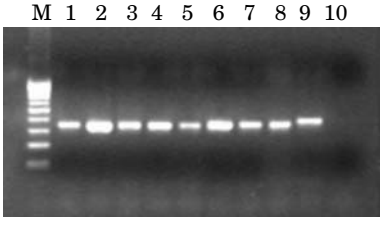

Fig. 1. PCR product obtained from spring wheat grain with the use of species-specific primers (PL58SL/PL28SL) for *Fusarium spp.* under water stress conditions in 2005. M – molecular weight standard 1–5 spring wheat cv. Nawra, control treatment, 6–10 – spring wheat cv. Nawra, water stress

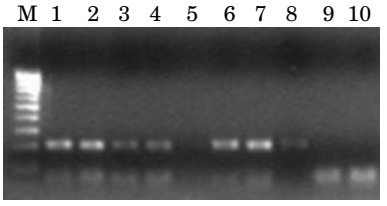

Fig. 2. PCR product obtained from spring wheat grain with the use of species-specific primers (Fp82R/Fp82R) for *Fusarium poae* under water stress conditions in 2005. M – molecular weight standard 1–5 spring wheat cv. Nawra, control treatment, 6–10 – spring wheat cv. Nawra, water stress

SCAR primers do not amplify plant DNA, but they permit pathogen identification directly in the host tissue, with no need for pure culture isolation. They also allow to detect infection at an early stage, and to recognize tissue damage prior to the onset of disease symptoms (CHEŁKOWSKI and WITKOWSKA 1999). The BIO-PCR technique enables to confirm the presence of live pathogen inoculum with potential infectious properties.

It should be stressed that PCR analyses may be an effective tool for presymptomatic diagnostics in plants, applied prior to the appearance of the signs and symptoms of a disease. According to reference data, in some cases pathogens had been identified before disease symptoms became apparent (TURNER et al. 1998).

Conclusions

1. Water deficit did not decrease the values of the investigated biometric characters of spring wheat plants, but it contributed to a drop in thousand grain weight and grain weight per plant.

2. Water stress resulted in a decrease in the values of gas exchange parameters, particularly in the rate of photosynthesis in the leaves of spring wheat.

3. Members of the genus *Penicillium* and toxin-producing fungi of the genus *Fusarium* were identified in wheat kernels. The rate of wheat grain colonization by fungal pathogens was slightly higher under water stress conditions.

4. The use of the BIO-PCR technique with species-specific SCAR primers permitted the detection of *Fusarium poae* in wheat grain.

Translated by ALEKSANDRA POPRAWSKA

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EVALUATION OF SEED YIELD VARIABILITY IN LP-TYPE LUCERNE (*MEDICAGO SATIVA* SSP. *MEDIA* L.) BASED ON SELECTED YIELD COMPONENTS

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K e y w o r d s: lucerne, lp-type, seed yield, principle component analysis (PCA), cluster analysis (CA), phenotypic diversity, repeatability.

A b s t r a c t

An experiment was established to study a population of long raceme peduncle-type (lp-type) lucerne. 15 groups of plants were grown in selection plots. Each group comprised plants originating from seeds collected from a single plant, and since lucerne is allogamous, the obtained results provided a basis for an evaluation within the maternal line. The aim of this study was to analyze the seed yield and the expression of phenotypic traits affecting the seed yield structure. Principle component analysis (PCA) was performed. The Euclidean distance and *K*-means grouping were used as a taxonomic measure of similarity between groups. Two agglomerated phenotypic groups were discriminated within the examined population, and the differentiating traits in a multivariate analysis were: number of racemes per shoot, number of seeds per shoot and seed yield per shoot. Statistical characteristics of the distinguished groups provided a basis for determining the ideotype with a high seed yield.

OCENA ZMIENNOŚCI PLONU NASION LUCERNY MIESZAŃCOWEJ DŁUGOGRONIASTEJ (*MEDICAGO SATIVA* SSP. *MEDIA* L.) W OPARCIU O WYBRANE ELEMENTY STRUKTURY PLONU

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S ł o w a k l u c z o w e: lucerna, forma „Lp”, plon nasion, analiza składowych głównych, analiza skupień, zróżnicowanie fenotypowe, powtarzalność.

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Abstrakt

W doświadczeniu, będącym podstawą tej pracy, badano populację roślin lucerny o długich kwiatostanach, formę „Lp". Do badań wybrano 15 grup roślin charakteryzujących się długimi gronami, które wysiano na poletkach selekcyjnych. Rośliny w grupie pochodziły z nasion zebranych z jednej rośliny, a ze względu na obcopylność lucerny, uzyskane wyniki traktowano jak ocenę po linii matecznej. Celem opracowania była analiza plonowania nasiennego i ekspresji cech fenotypowych składających się na strukturę plonu nasion. Zastosowano analizę składowych głównych. Jako taksonomiczną miarę podobieństwa między grupami wybrano odległości euklidesowe i grupowanie metodą *k*-średnich. Stwierdzono aglomerację badanej populacji lucerny mieszańcowej na dwie wyraźne grupy fenotypowe. Cechami różnicującymi w analizie wielowymiarowej były: liczba gron na pędzie, liczba nasion z pędu oraz plon nasion z pędu. Sporządzono charakterystykę statystyczną wydzielonych grup. Na tej podstawie sporządzono ideotyp formy o wysokim plonie nasion.

Introduction

The evaluation of variability regarding seed yield and yield-forming factors is an important stage of breeding work. However, yield estimation and prediction in a collection population is extremely difficult. In the lucerne breeding experiments presented in this paper, the authors evaluated the seed production potential of initial material. Lp-type lucerne plants were analyzed. Lucerne is an allogamous and perennial crop whose green matter yield and seed yield are harvested in the second and following years, therefore its varietal stability is hard to determine. Discovering certain common, unknown factors responsible for dependencies between variables (...), or in other words presenting observable variables in the form of a smaller number of non-observable (hidden) variables referred to as factors (...) (MORRISON 1990), may be used for the purpose of dividing the initial material into homogeneous groups, each with a specific set of attributes. Early selection and reproductive isolation of the discriminated groups, based on a multivariate analysis, may contribute to progress in breeding work. Other important aspects are the determination of repeatability of results in particular years of lucerne growing, and the variation of trait values within and between progeny groups.

The aim of this study was to determine the traits having the greatest discriminant value, differentiating the investigated population of lp-type luicerne plants. This will enable to select progeny groups with the highest seed production potential.

Materials and Methods

A collection of lucerne plants analyzed in this study was established in 2003 in the village of Raczyny, commune of Przesmyki, situated in the eastern part

of the Masovian Province. The material was supplied by dr Zbigniew Bodzon from the Department of Genetics, Institute of Plant Breeding and Acclimatization in Radzików. The lp phenotype was selected of the RAH 100 population. 15 groups of plants were grown in selection plots. Each group comprised plants originating from seeds collected from a single plant, and since lucerne is allogamous, the obtained results provided a basis for an evaluation within the maternal line. The following yield-forming traits were considered: shoot length, number of nodes per shoot, number of racemes per shoot, length of the receptacle and of its productive part, average number of pods and seeds per raceme, average number of seeds per pod, number of seeds per shoot, thousand seed weight and seed yield per shoot.

The statistical characteristics of the examined population included the mean, maximum and minimum value, and the coefficient of variation for each of the analyzed traits. The coefficients of correlation ($n=15$) between traits, determined in 2004 and 2005, were used as a measure of the repeatability of results in particular years of lucerne growing. An analysis of variance in a one-factor design provided a basis for calculating the coefficients of trait heritability in consecutive years (FALCONER 1974, JANICKI, SOBEK 1989, PŁOCHIŃSKI 1968, SKOLASIŃSKI, CHARON 1987). The coefficient of heritability describes the diversity of groups of plants with a similar genotype, but of different origin. A comparison of the values of heritability coefficients in particular years allows to determine the effect of of non-genetic factors on this diversity.

A multivariate analysis was performed by the principle components method. The Euclidean distance was used as a taxonomic measure of similarity between groups, and cluster analysis involving *K*-means grouping was carried out (SIECZKO et al. 2004, LIU et al. 2004, JAMES et al. 2000, ROJAS et al. 2000, *Statystyczne metody...* 1999, ZEVEN et al. 1999, MĄDRY 1993, MAREK 1989). PCA was conducted based on the matrix of correlation coefficients R for mean values of two years and 11 investigated traits. The estimates of eigenvalues (characteristic values) $\hat{\lambda}_i$ of the correlation matrix R and the corresponding estimates of eigenvectors w_i were determined. The coefficient of simple correlation $r_{\hat{z}_i x_j}$ between the i-th principle component and the j-th observable variable (trait) was calculated using the formula (SIECZKO et al. 2004):

$$r_{\hat{z}_i x_j} = \frac{w_{ij}\sqrt{\hat{\lambda}_i}}{S_j^2}$$

where:
S_j^2 – estimate of variance of the j-th trait x_j (j-th element on the diagonal of the covariance matrix S; w_{ij} – elements of the i-th eigenvector for the j-th observable variable (trait) x_j, $j = 1,...,p$.
Calculations were performed using Statistica software.

Results and Discussion

An analysis of the obtained results revealed that the examined lucerne population was characterized by relatively high diversity (Table 1). Seed yield per shoot showed the highest variability within population (V=74%). Slightly lower values of the coefficient of variation were observed for the number of seeds per shoot (V=67%), the average number of seeds per pod (V=62%) and the average number of seeds per raceme (V=55%). Low variability was noted with respect to receptacle length (V=16%), shoot length (V=24%) and thousand seed weight (V=25%). The minimum values of the analyzed traits were most often recorded in group 3 shoots. Single plants showing the maximum expression of individual traits were most frequently noted in groups 4, 5, 6, 9 (Table 1).

Table 1

Characteristics of trait variation for lp-type lucerne forms (2004–2005)

Specification	Mean	Minimum	Maximum	Coefficient of variation
Shoot length (cm)	92.8	39^{13*}	142^{5}	24
Number of nodes per shoot	18.1	6^{15}	26^{3}	46
Number of racemes per shoot	48.1	6^{6}	122^{5}	51
Average number of pods per raceme	13.4	6.1^{4}	30.2^{6}	25
Receptacle length (cm)	5.9	4.8^{13}	12.3^{9}	16
Length of the productive part of receptacle (cm)	3.4	2.2^{12}	9.02^{9}	30
Average number of seeds per raceme	19.3	3.3^{3}	58.7^{6}	55
Average number of seeds per pod	1.0	0.80^{6}	2.9^{12}	62
Number of seeds per shoot	722.7	86^{3}	2741^{4}	67
Thousand seed weight (g)	1.74	1.0^{3}	4.0^{8}	25
Seed yield per shoot (g)	1.3	0.5^{3}	6.42^{4}	74

* – numbers denote genetic forms from which single plants with extreme values of traits originated

Table 2 presents an evaluation of diversity within progeny groups of lp-type lucerne. The coefficients of heritability, determined based on an analysis of variance in a randomized one-factor design, were used. These coefficients served as a measure of diversity within groups of plants, and of the effect of non-genetic factors on this diversity. An analysis of the coefficients of heritability revealed that the number of nodes, the length of the receptacle and of its productive part, and the number of seeds per raceme showed the highest degree of heritability, repeatable in the years of study. This is indicative of a relatively high diversity of groups of plants on the one hand, and of genetic similarity within groups with respect to the above traits on the other.

Table 2
Evaluation of diversity within progeny groups (h^2) of lp-type lucerne (*Medicago sativa*) plants and repeatability of expression of the examined traits in the years 2004 and 2005

Specification	2004	2005	Coefficients of correlation between traits in the years of study
Shoot length (cm)	0.11	0.26*	0.19
Number of nodes per shoot	0.47*	0.53*	0.33
Number of racemes per shoot	0.18*	0.00	-0.06
Average number of pods per raceme	0.13*	0.03	0.36
Receptacle length (cm)	0.41*	0.31*	**0.50***
Length of the productive part of receptacle (cm)	0.51*	0.54*	**0.59***
Average number of seeds per raceme	0.43*	0.34*	**-0.68***
Average number of seeds per pod	0.32*	0.00	0.24
Number of seeds per shoot	0.14*	0.14*	**-0.51***
Thousand seed weight (g)	0.03	0.98	0.26
Seed yield per shoot (g)	0.15*	0.18*	**-0.49***

* – significant at $\alpha = 0.05$

The coefficients of correlation were calculated between the years of study, for particular traits represented by mean values determined for each of the analyzed groups of lucerne plants. In case of full repeatability of traits in years, the correlation coefficient would be close to 1. The following traits were characterized by the highest degree of repeatability: number of seeds per raceme (-0.68), length of the receptacle (0.45) and of its productive part (0.59), number of seeds per plant (-0.51), number of seeds per shoot (-0.41). The remaining traits, which developed earlier during ontogenesis, showed low repeatability.

A low proportion of genetic variation in total variation in groups of plants, as well as high values of heritability coefficients and repeatability of results in years, may provide a basis for predicting trait expression in successive years. Therefore, a question arises whether a set of selected traits and their expression e.g. in the first year of lucerne growing may contribute to predicting their expression in following years.

Multivariate methods are employed to determine trait variation in lucerne populations, but primarily they are applied in studies using genetic markers, DNA analysis and chromosomal similarity (BAUCHAN et al. 2003, JENCZEWSKI et al. 1999, BENA et al. 1998, BARACCIA et al. 1997). Many authors have successfully deployed the above methods to evaluate population variability of agricultural (KUBICKA et al. 2004, KURIATA et al. 2004, MĄDRY 1993,

NOFFSINGER 2000, PIETRZYKOWSKI 2004, SIECZKO et al. 2004, TYRKA, MIKULSKI 2004, RONFORT et al. 1998) and horticultural plants (UKALSKA et al. 2004).

A principle component analysis (Table 3) revealed that the first two components explained 48% of the total multifactor variation of the studied genetic forms of lucerne. The number of racemes per shoot, the number of seeds per shoot and the seed yield per shoot showed the strongest correlation with the first principle component, and significantly differentiated the investigated homogeneous groups. As regards the second principal components, the highest discriminant value was noted for the length of the receptacle and of its productive part.

Table 3

Eigenvalues for two principal components and coefficients of correlation $r_{\hat{z}_i x_j}$

Trait	Component 1 ($\hat{z}_1$)	Component 2 ($\hat{z}_2$)
	correlation coefficients $r_{\hat{z}_i x_j}$	correlation coefficients $r_{\hat{z}_i x_j}$
Shoot length	0.061	0.209
Number of nodes per shoot	0.285	0.427
Number of racemes per shoot	0.878	-0.016
Average number of pods per raceme	-0.161	-0.099
Receptacle length (cm)	0.102	**0.842**
Length of the productive part of receptacle (cm)	0.364	0.769
Average number of seeds per raceme	0.309	-0.622
Average number of seeds per pod	-0.288	0.016
Number of seeds per shoot	0.938	-0.307
Thousand seed weight (g)	0.270	0.436
Seed yield per shoot (g)	**0.948**	-0.143
Eigenvalues $\hat{\lambda}_i$	3.05	2.23
Percentage of explained multifactor variation	27.8	20.2

As indicated by the diagram presented in Figure 1 and by *K*-means grouping, the examined groups of single plants could be divided into two clusters. The first cluster comprised high-seed-yielding forms with the following numbers: 1, 4, 5, 6, 9, 10, 14, 15. The other cluster included the remaining groups of individual plants (2, 3, 7, 8, 11, 12, 13). Mean values of traits for both clusters are presented in Table 4. The traits differentiating the analyzed groups of individual plants were: number of racemes per shoot, average number of seeds per pod, yield and number of seeds per shoot; the traits had been determined earlier by the principle component analysis.

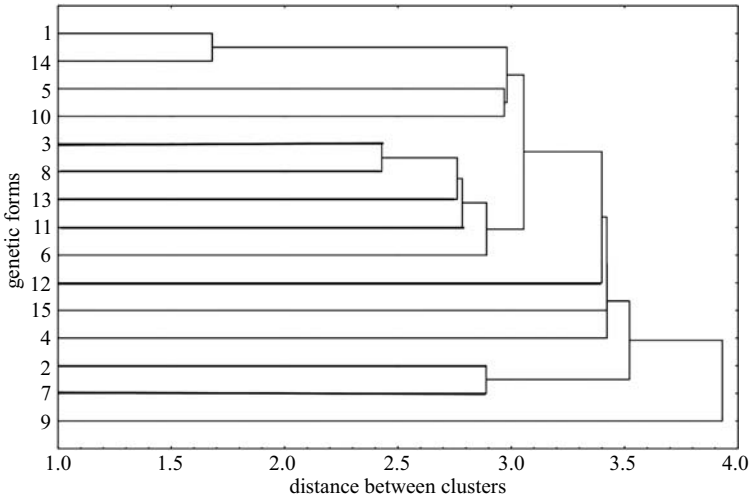

Fig. 1. Diagram for 15 forms of lucerne

Table 4

Mean values of the examined traits for clusters

Specification	Mean values of traits for cluster 1	Mean values of traits for cluster 2	Level of significance of differences between clusters
Shoot length (cm)	93.9	88.3	0.41
Number of nodes per shoot	17.5	15.6	0.42
Number of racemes per shoot	$55.3^{4.1*}$	32.8	**0.01**
Average number of pods per raceme	13.1	13.5	0.63
Receptacle length (cm)	5.9	5.7	0.43
Length of the productive part of receptacle (cm)	3.4	3.0	0.23
Average number of seeds per raceme	20.1	17.3	0.31
Average number of seeds per pod	0.9^{4}	1.3	**0.05**
Number of seeds per shoot	$882.6^{4.15}$	457.3	**0.01**
Thousand seed weight (g)	1.75^{4}	1.7	0.72
Seed yield per shoot (g)	$1.57^{4.15}$	0.8	**0.01**

* – numbers of groups of single plants with the highest values of traits in a cluster

Shoots marked by high seed productivity (1.57 g seeds per shoot on average) set approximately 883 seeds each (Table 4). The pods on these shoots set a relatively low number of seeds – one seed per pod on average, whereas the number of seeds per raceme amounted to 20. The relationship between seed yield and the number of seeds set per raceme has been described by STA-

SZEWSKI (1975), PUZIO-IDŹKOWSKA (1993). As demonstrated in a previous study conducted by a co-author of the present paper (WYRZYKOWSKA 2004), high--yielding lucerne plants set many seeds per shoot and per raceme.

Long peduncles are not always correlated with high seed productivity. The groups of plants classified into the second cluster produced a low seed yield. According to data from field observations, long peduncles are often poor in seeds. Low raceme compactness may be caused by poor seed set (due to weather conditions, insect invasions, short-term flower viability) or by seed breaking during harvest.

Based on the obtained results, the following forms were selected for further breeding: 1, 4, 15. Their high breeding value was confirmed over two years of utilization.

Conclusions

1. A principle component analysis revealed that the first two components explained 48% of the total multifactor variation of the examined groups of plants. The number of racemes per shoot, the number of seeds per shoot and the seed yield per shoot showed the strongest correlation with the first principle component. These traits had the greatest discriminant value.

2. A multivariate analysis allowed to divide the examined lucerne population into two homogeneous groups differing significantly with regard to seed production potential and traits characterizing seed yield. The first cluster comprised high-seed-yielding forms with the following numbers: 1, 4, 5, 6, 9, 10, 14, 15.

3. Selected plants marked by high seed productivity (1.57 g seeds per shoot on average) set approximately 883 seeds each, one seed per pod and 20 seeds per raceme.

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EFFECT OF DISEASE INCIDENCE ON THE MILK PERFORMANCE OF HIGH-YIELDING COWS IN SUCCESSIVE LACTATIONS*

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Key words: health status of cows, mastitis, endometritis, lameness, ketosis, ovarian cysts, milk yield, fat, protein.

Abstract

The study was conducted in the years 2006–2008. The experimental materials comprised 368 Holstein-Friesian cows purchased from Germany as in-calf heifers. The objective of this study was to determine the health status of cows in a commercial herd kept in the Olsztyn region, based on the type and incidence of diseases that occurred during three consecutive lactations, and to analyze the effect of these diseases on milk yield and composition in the first, second and third lactation cycle. The cows were divided into five groups: HEA – clinically healthy cows (showing no disease symptoms), MAS – cows with mastitis, LAM – cows with foot/leg defects and lameness, REP – cows with reproductive problems (retention of the placenta, endometritis, ovarian cysts), MET – cows with metabolic diseases (ketosis, abomasal displacement). It was found that the most common diseases during three consecutive lactations in the investigated herd were endometritis (37.63%) which occurred soon after calving (on day 18 post-partum), mastitis (35.48%), formation of ovarian cysts (10.10%), ketosis (8.39%) and leg/foot defects (6.44%). Retention of the placenta and abomasal displacement were diagnosed much less frequently (1.62% and 0.34% respectively). The percentage of healthy cows decreased in successive lactations (19.81% in the first lactation, 12.28% in the second lactation, 6.22% in the third lactation). During each lactation, more than one third of cows suffered from mastitis. The proportion of cows showing the symptoms of ketosis increased with age, from 5.12% in the first lactation to 12.23% in the third lactation. The highest yields of milk and milk components over a 305-day lactation cycle were noted in cows with reproductive diseases (ROZ). Foot/led defects and lameness (LAM), mastitis (MAS) and metabolic diseases (MET) had the most significant effect on a decrease in milk production.

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WPŁYW RODZAJU SCHORZEŃ U KRÓW WYSOKO WYDAJNYCH NA ICH UŻYTKOWOŚĆ MLECZNĄ W KOLEJNYCH LAKTACJACH

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S ł o w a k l u c z o w e: zdrowotność krów, *mastitis*, *endometritis*, kulawizny, ketoza, cysty jajnikowe, wydajność mleka, tluszcz, białko.

A b s t r a k t

Badania przeprowadzono w latach 2006–2008. Materiał badawczy stanowiło 368 krów rasy holsztyńsko-fryzyjskiej zakupionych jako jałówki cielne z Niemiec. Celem badań była ocena stanu zdrowotnego krów na podstawie rodzaju i częstotliwości występowania chorób w 3 kolejnych laktacjach, a także określenie ich wpływu na wydajność i skład mleka w I, II i III laktacji zwierząt użytkowanych w hodowli wielkostadnej w regionie olsztyńskim. Wszystkie krowy w stadzie podzielono na 5 grup zdrowotnych: ZDR – krowy zdrowe (bez objawów chorobowych); MAS – krowy z zapaleniem wymienia (*mastitis*); KUL – krowy z chorobami racic (kulawizny); ROZ – krowy z chorobami układu rozrodczego (zatrzymanie łożyska, zapalenie błony śluzowej macicy [*endometritis*], cysty jajnikowe); MET – krowy z chorobami metabolicznymi (ketoza, przemieszczenie trawieńca). W stadzie wysoko wydajnych krów odnotowano, że w trzech analizowanych laktacjach najczęściej stwierdzanymi chorobami były: zapalenia błony śluzowej macicy (37,63%), pojawiające się najwcześniej po wycieleniu (w 18 dniu), zapalenia wymienia (35,48%), a następnie cysty jajnikowe (10,10%), ketoza (8,39%) i kulawizny (6,44%); znacznie rzadziej diagnozowano zatrzymanie łożyska (1,62%) i przemieszczenie trawieńca (0,34%). Udział krów zdrowych zmniejszał się w kolejnych laktacjach, wynosząc w I laktacji 19,81%, w II – 12,28% i w III – tylko 6,22%. W każdej laktacji ponad 1/3 krów w stadzie zapadała na *mastitis*. Wraz z wiekiem wzrastał także udział krów z objawami ketozy z 5,12% (w I laktacji) do 12,23% (w III laktacji). Najwyższą wydajność mleka i jego składników w laktacji 305-dniowej odnotowano u krów z chorobami układu rozrodczego (ROZ). Największy wpływ na obniżenie produkcji mleka i jego składników miały choroby związane z układem ruchu (KUL), *mastitis* (MAS) oraz choroby metaboliczne (MET).

Introduction

The health status of cattle is affected by livestock production intensification (MALINOWSKI et al. 2003, WROŃSKI et al. 2007). The breeding programs aimed at improving overall cow performance lead to general herd health deterioration, which is manifested in a higher disease incidence and a decrease in fertility. The most common health problems include metabolic diseases, reproductive diseases and motor system disorders (TWARDOŃ et al. 2001, JANOWSKI 2004, WÓJCIK 2005). As a result, the yields of milk and milk components decrease. According to FLEISCHER et al. (2001), since the correla-

tion between milk yield and disease incidence rates has not been proved, it should be assumed that high-producing cows are not more susceptible to diseases, provided that their maintenance and production needs are met. SHAVER (1997) pointed to the importance of adequate nutrition and well-being of cows during the perinatal period, when cows are particularly prone to abomasal displacement. The findings of other authors suggest that a significant increase in milk yield may be associated with such health problems as metabolic diseases, reproductive diseases and mastistis, as well as with higher feed costs and a deterioration in the nutritional value of milk (COPPOCK 1973, EMPEL et al. 1986, CORREA et al. 1993, KONDRACKI 2001). The above negative processes result in higher costs of medical treatment, a shorter herd life, reduced revenues from milk sales and, in consequence, lower milk production profitability (BRZOZOWSKI et al. 2003, DORYNEK et al. 2005).

The objective of this study was to determine the health status of cows in a commercial herd kept in the Olsztyn region, based on the type and incidence of selected diseases that occurred during three consecutive lactations, and to analyze the effect of these diseases on milk yield and composition.

Materials and Methods

The study was conducted in the years 2006–2008. The experimental materials comprised 368 Holstein-Friesian cows purchased from Germany as in-calf heifers. The cows were kept in four free-stall barns, on deep litter, under the indoor feeding system. The mono diet fed to cows was based on succulent roughage: hay silage, corn-cob-mix and corn garin silage as well as soybean meal, rapeseed meal, ground rye, pelleted concentrated feed "Focus" (Cargill, Poland) and a "Super Premium" vitamin premix. The diet was supplemented with diamond yeast metabolites, limestone, salt lick and sodium bicarbonate. Total mixed rations (TMR) were administered from a movable feed cart into feeders inside the barns. The cows were divided into five technological groups, based on their performance and physiological condition. Average daily milk yield in each group was as follows: group 1 – over 40 kg, group 2–31 to 40 kg, group 3–15 to 30 kg, group 4 – below 15 kg. Group 5 comprised dry cows.

Cows were milked twice daily in two herringbone milking parlors (2 x 7, Fullwood Limited Ellesmere Shropshire, England). Due to daily collection, milk was cooled to 6°C. Technological processes were managed and controlled with the use of Afifarm v.2. 05F software. The herd was regularly inspected by a veterinary surgeon. The following milk performance parameters were analyzed: the yields of milk, fat, protein and dry matter, and the percentage content of milk components over 305 days of the first, second and third

lactation, as dependent on disease incidence. Actual milk yield was converted into the yield of value-corrected milk (VCM) (kg), according to the following formula:

$$\text{VCM (kg)} = -0.05\ x\ \text{(milk kg)} + 8.66\ x\ \text{(fat kg)} + 25.98\ x\ \text{(protein kg)}$$

(ARBEL et al. 2001).

Based on their health status, the cows were divided into five groups: HEA – clinically healthy cows (showing no disease symptoms), MAS – cows with mastitis and other udder diseases, LAM – cows with foot/leg defects (lameness, foul-in-the-foot), REP – cows with reproductive problems (retention of the placenta, endometritis, ovarian cysts), MET – cows with metabolic diseases (ketosis, abomasal displacement). The analysis did not include cows in which more than one disease was diagnosed.

The results were processed statistically using Statistica ver. 7.1 software. Least square means (LSM) and standard errors (Se) were determined by a one-factor analysis of variance, and the significance of differences between means was estimated by Duncan's test.

Results and Discussion

Disease incidence in groups of cows over three consecutive lactations is presented in Table 1. The percentage of healthy cows decreased gradually during successive lactation cycles. In each lactation, over 30% of cows were affected by reproductive problems (REP), including endometritis, formation of ovarian cysts and retained placenta (32.47%, 31.10% and 36.20% in the first, second and third lactation respectively). In a study conducted by FLEISCHER et al. (2001), the most common diseases observed in lactating cows were metritis (23.0%) and mastitis (21.6%), followed by the occurrence of ovarian cysts (11.7%) and abomasal displacement (1.1%). HINRICHS et al. (2006) also reported that reproductive disorders were diagnosed most frequently in lactating cows.

The second most common disease was mastitis (MAS). Disease incidence rates increased with cow's age (from 22.73% in primiparous cows to 27.23% in the oldest cows). According to MALINOWSKI et al. (2003), mastitis remains the most frequent disease in dairy cattle herds, and the treatment of this condition generates the highest costs. These authors examined 972 cows in western Poland, and observed the clinical symptoms of mastitis in 15.1% of the population. They concluded that effective mastitis control requires both regular herd monitoring and the implementation of new prevention and treatment programs.

Table 1

Disease incidence in groups of cows over three consecutive lactations

Group of cows	Lactation						Average	
	I		II		III			
	n	%	*n*	%	N*	%	*n*	%
HEA	61	19.81	40	12.28	19	6.22	40	12.77
MAS	70	22.73	81	24.73	52	27.23	68	24.90
LAM	47	15.26	7	2.54	–	–	27	8.90
REP	100	32.47	95	31.10	69	36.30	88	33.29
MET	30	9.73	35	12.47	37	18.85	34	13.68
TOTAL	308	100	256	83.12	191	62.01	882	81.71

* number of cases

Cows with foot and leg defects had the lowest share among the analyzed groups (Table 1). They accounted for 15.26% of the studied population in the first lactation and for 2.54% in the second lactation, while no cases of lameness were noted in the third lactation. This could result from the fact that as many as 43 cows (11.68%) were culled for health disorders in the second lactation, and a total of 177 cows (48.10%) were culled in the second and third lactation. TWARDOŃ et al. (2001) demonstrated that on dairy farms over 15% of cows suffer from lameness. According to these authors, the most prevalent reasons for lameness include too high milk production levels, feeding excessive amounts of high-protein concentrate and insufficient amounts of high-energy feed to cows, genetic factors and inadequate foot care. EMPEL et al. (1986), and POGORZELSKA and LEWAROWSKI (2005) reported that hoof health is affected by housing conditions, as foot and leg abnormalities are much more common in the tie-stall system than in the free-stall system.

Endometritis was diagnosed most frequently in the investigated herd (Table 2), i.e. in more than 36% of cows in every lactation. CORREA et al. (1993) found that metritis causes massive economic losses on dairy farms, being the main reason for culling due to decreased milk production and impaired reproduction.

A high incidence of mastitis was noted in the present study (32.62%, 37.37% and 36.78% of cows in the first, second and third lactation respectively). Other frequently occurring health disorders in the analyzed herd were the formation of ovarian cysts (10.40%), lameness (6.44%) and retention of the placenta (1.62%). The most prevalent metabolic diseases (Table 2) were ketosis (8.39%) and abomasal displacement (0.34%).

In a study performed by FLEISCHER et al. (2001), the percentage of cows with metabolic diseases (acidosis, ruminal alkalosis and ketosis) increased in successive lactations. According to the above authors, this could be related

Table 2

Types of diseases diagnosed in cows during three consecutive lactations

Type of disease	Lactation						Average	
	I		II		III			
	N*	%	*n*	%	N	%	*n*	%
Endometritis	271	37.22	321	38.77	179	36.14	257	37.63
Mastitis	237	32.62	308	37.37	182	36.78	242.3	35.48
Formation of ovarian cysts	80	10.97	69	8.32	58	11.70	69	10.10
Ketosis	37	5.12	76	9.23	59	12.23	57.3	8.39
Lameness	88	12.03	44	5.29	–	–	44	6.44
Retention of the placenta	15	2.04	7	0.85	11	2.24	11	1.62
Abomasal displacement	–	–	2	0.17	5	0.91	2.3	0.34
Total	728	100	827	100	494	100	682.9	100

* – number of cases

to the diet whose influence on the health status of cows is particularly important at high milk production levels, reaching 7 to 10 000 kg per lactation. This relationship was also observed by BOHDANOWICZ-ZULA et al. (2004) who found that an increase in milk yield is often accompanied by the occurrence of metabolic diseases, especially at the first stage of lactation, due to the imbalance between milk production levels and nutrient supply and intake.

According to MALINOWSKI and KACZMAROWSKI (2003), the reasons for retention of the placenta in cows are complex and have not been fully elucidated yet. Retained placenta is a risk factor for both acute and chronic post-partum endometritis and the formation of ovarian cysts. The negative impact of retained placenta on the reproductive performance of dairy cows, leading to increased culling rates, has also been documented.

The time of disease occurrence after calving is shown in Table 3. Endometritis was diagnosed soonest after calving (18 days post-partum on average). In the oldest cows the symptoms appeared as early as on day 16 post-partum in the third lactation. Motor system disorders, including lameness, were recorded much later, on day 150 post-partum on average. Their occurrence is closely correlated with the age of cows, since younger animals generally have healthier legs and feet. During the first and third lactation, lame cows were detected within 194 and 82 days post-partum respectively. Mastitis was diagnosed on day 81 after calving in the third lactation, while in primiparous cows the symptoms of this disease were observed two months later. A decrease in cow performance was noted after recovery, ending the period of maximum milk production.

Table 3

Time of disease occurrence (days post-partum)

Type of disease	Lactation			
	I	II	III	Average
Endometritis	20	19	16	18
Mastitis	139	104	81	108
Formation of ovarian cysts	116	107	62	95
Lameness	194	173	82	150
Ketosis	40	30	35	35

GIL et al. (2007) studied the relationship between milk performance and fertility indicators in dairy cows and found that an increase in milk yield was accompanied by extended inter-pregnancy interval. Ovarian cysts and chronic endometritis were detected in 19% and 21% of the analyzed population respectively. STEVENSON and CALL (1988) demonstrated that the formation of ovarian cysts (diagnosed in 47% of cows) is observed most frequently between day 31 and 60 post-partum. Ovarian cysts are detected more often in older cows. Cows aged from 7 to 10 years are more prone to developing ovarian cysts than those aged 2 to 7 years. These regularities were not confirmed in the present study. NOGALSKI and GÓRAK (2007) stress the fact that blood analyses performed at the first stage of lactation may be a helpful reproductive management tool enabling to evaluate the metabolic profile of cows and to predict the optimum time for insemination. According to the above authors, conception rates can be increased in high-producing cows by prolonging the rest period after calving.

Milk yield and composition over three 305-day lactations, as dependent on the health status of cows, are presented in Table 4. In the first and second lactation, clinically healthy cows (HEA) were characterized by productivity exceeding 9000 kg milk. An even higher milk yield, i.e. 9487 kg in the second lactation and 9254 kg in the third lactation, was recorded in group 4 cows (REP).

GRÖHN et al. (1995) reported that reproductive disorders (metritis, ovarian cysts and retained placenta) had no effect on milk production levels, while RAJALA and GRÖHN (1998) demonstrated a negative impact of retained placenta on milk yield within a few weeks after the first calving. In a study conducted by STEVENSON and CALL (1988), cow productivity did not change during retention of the placenta, but this disorder caused a significant decrease in daily milk yield expressed in kg over the entire production cycle. STEVENSON and CALL (1988) pointed to an increase in milk production in cows with ovarian cysts over 305-day lactation, but during the extended inter-calving interval milk yield decreased by 2.5%. According to these authors, a high milk yield during

Table 4

Milk yield and composition in three 305-day lactations as dependent on the heath status of cows

Trait	Lactation	Group of cows									
		HEA		MAS		LAM		REP		MET	
		LSM	Se	LSM	Se	LSM	Se	LSM	Se	LSM	Se
Milk (kg)	I	7027^{A}	288	7355^{B}	302	8314^{C}	253	6997^{A}	273	6779^{A}	265
	II	9235^{A}	338	8804^{B}	403	8220^{C}	586	9487^{D}	412	8299^{C}	413
	III	9186^{A}	872	7610^{B}	406	8320^{C}	564	9254^{A}	551	7310^{D}	414
Significance of differences		$2.3>1^{xx}$		$2>3.1^{xx}$; $3>1^{x}$		$1.3>2^{xx}$		$2.3>1xx$; $2>3^{x}$		$2.3>1^{xx}$	
VCM (kg)	I	7665^{A}	279	8517^{B}	290	9414^{C}	294	8059^{D}	258	7555^{E}	248
	II	10112^{A}	293	9585^{B}	362	9389^{B}	608	10119^{A}	378	9177^{B}	376
	III	9898^{a}	589	9592^{b}	586	8423^{b}	725	10311^{c}	448	8456^{d}	441
Significance of differences		$2.3>1^{xx}$; $2>3^{x}$		$2.3>1^{xx}$		$1.2>3^{xx}$		$2.3>1^{xx}$		$2.3>1^{xx}$; $2>3^{x}$	
Fat (kg)	I	265^{A}	9.29	297^{B}	10.79	339^{B}	12.34	290^{A}	9.10	264^{A}	7.95
	II	343^{A}	11.32	353^{A}	11.28	348^{A}	25.00	353^{A}	10.14	321^{B}	13.77
	III	351^{A}	12.34	301^{B}	20.06	344^{B}	25.07	369^{A}	10.96	301^{A}	12.36
Significance of differences		$2.3>1^{xx}$		$2>1.3^{xx}$		n.s.d.		$2.3>1^{x}$		$2.3>1^{xx}$	
Fat (%)	I	3.77^{A}	0.12	4.04^{B}	0.13	4.08^{B}	0.09	4.14^{B}	0.09	3.90^{C}	0.13
	II	3.72^{A}	0.14	4.01^{B}	0.13	4.24^{C}	0.20	3.72^{A}	0.12	3.87^{D}	0.13
	III	3.82^{A}	0.45	3.96^{B}	0.11	4.14^{B}	0.19	3.99^{A}	0.13	4.12^{B}	0.12
Significance of differences		$3.1>2^{x}$		$1.2>3^{x}$		$2.3>1^{x}$		$1>3.2^{xx}$; $3>2^{x}$		$3.1>2^{xx}$	
Protein (kg)	I	235^{A}	9.01	256^{B}	9.67	274^{C}	7.90	240^{A}	7.54	230^{A}	8.04
	II	313^{A}	9.01	300^{A}	11.45	279^{B}	17.00	313^{A}	13.21	282^{B}	11.13
	III	303^{A}	25.86	261^{B}	17.02	285^{B}	21.20	317^{A}	14.96	250^{B}	11.50
Significance of differences		$2.3>1^{xx}$		$2>1.3^{xx}$		n.s.d.		$3.2>1^{xx}$		$2.3>1^{xx}$	
Protein (%)	I	3.35^{a}	0.04	3.48^{b}	0.05	3.29^{a}	0.04	3.43^{b}	0.05	3.40^{b}	0.07
	II	3.39^{a}	0.04	3.41^{a}	0.07	3.40^{a}	0.07	3.30^{b}	0.05	3.40^{a}	0.06
	III	3.30^{a}	0.07	3.43^{b}	0.07	3.43^{b}	0.05	3.43^{b}	0.08	3.42^{b}	0.04
Significance of differences		$2>1.3^{x}$		n.s.d.		$3>1^{x}$		$1.3>2^{x}$		n.s.d.	
Dry matter (kg)	I	854^{a}	25.42	926^{b}	34.24	1031^{c}	32.81	887^{a}	29.31	862^{a}	33.50
	II	1116^{a}	33.00	1083^{b}	41.66	1031^{b}	69.35	1127^{a}	42.77	1010^{b}	45.18
	III	1097^{a}	65.17	921^{b}	58.81	1029^{b}	77.06	1145^{c}	55.20	903^{a}	46.57
Significance of differences		$2.3>1^{xx}$; $2>3^{x}$		$2>1.3^{xx}$		n.s.d.		$3.2>1^{xx}$		$2>1.3^{xx}$	
Dry matter (%)	I	12.15^{a}	0.17	12.59^{b}	0.16	12.40^{b}	0.11	12.68^{c}	0.13	12.72^{c}	0.31
	II	12.09^{a}	0.17	12.30^{b}	0.18	12.54^{c}	0.25	11.88^{d}	0.14	12.17^{e}	0.19
	III	11.94^{a}	0.51	12.10^{b}	0.16	12.37^{c}	0.25	12.37^{c}	0.25	12.35^{c}	0.13
Significance of differences		$1>3^{xx}$; $1>2^{x}$		$1>2.3^{x}$		$2>1.3^{x}$		$1.3>2^{x}$		$1>3.2^{x}$	

Significance of differences between groups: *A, B* at $p \leq 0.01$ and *a, b* at $p \leq 0.05$;
Significance of differences between lactations: xx – $p \leq 0.01$ and x – $p \leq 0.05$.
n.s.d. – non-significant difference

previous lactations and a high genetic potential of cows do not contribute to disease occurrence.

In the present study the lowest milk yield was reported for cows with metabolic disorders (MET) – 6779 kg milk in the first lactation, 8299 kg milk in the second lactation and 7310 kg milk in the third lactation. Substantially higher productivity was noted when actual milk yield was converted into the yield of value-corrected milk (VCM), which exceeded 10 000 kg milk in healthy cows in the second lactation (10 112 kg) and in cows with reproductive diseases in the second and third lactation (10 119 kg and 10 311 kg respectively).

Regardless of the group, milk fat yield was lower in the first lactation (264 to 339 kg) than in the next two lactations. The highest fat yield was reported for the oldest cows of group 4 (REP) (369 kg). The same trend was noted with respect to milk protein yield, which was the lowest in the first lactation (230 to 274 kg). As regards the percentage content of milk components, the highest values were observed in cows characterized by the lowest milk yield, whereas the lowest – in cows marked by the highest milk yield. MICIŃSKI et al. (2008) analyzed disease incidence in dairy cattle herds and found that the highest-producing cows were most susceptible to diseases.

Conclusions

It was found that the most common diseases during three consecutive lactations in the investigated herd were endometritis (37.63%) which occurred soon after calving (on day 18 post-partum), mastitis (35.48%), formation of ovarian cysts (10.10%), ketosis (8.39%) and leg/foot defects (6.44%). Retention of the placenta and abomasal displacement were diagnosed much less frequently (1.62% and 0.34% respectively). The percentage of healthy cows decreased in successive lactations (19.81% in the first lactation, 12.28% in the second lactation, 6.22% in the third lactation). During each lactation, more than one third of cows suffered from mastitis. The proportion of cows showing the symptoms of ketosis increased with age, from 5.12% in the first lactation to 12.23% in the third lactation. The highest yields of milk and milk components over a 305-day lactation cycle were noted in cows with reproductive diseases. Foot/led defects and lameness, mastitis and metabolic diseases had the most significant effect on a decrease in milk production.

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FAT THICKNESS AND THE LONGEST BACK MUSCLE MEASUREMENT OF CARCASSES OF FATTENERS SLAUGHTERED AT DIFFERENT WEIGHT

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K e y w o r d s: fatteners, fat thickness, the longest back muscle measurements, different carcass weight.

A b s t r a c t

The research was conducted on 286 fattener carcasses chosen from mass population in three different regions of the country. On the carcasses, fat thickness measurements were performed on the carcass cross section as well as fat and the longest back muscle thickness measurements on two cross sections of the loin. Carcasses, depending on their weight, were divided into three groups, i.e. of the average weight of about 70, 80 and 90 kg. Research showed that the increase of carcass weight by about 10 kg in the case of fatteners bought by meat plants caused statistically significant increase of fat thickness and measurement results of the longest back muscle in all measured points. The increase of carcass weight from 70.0 to 80.0 kg caused relatively small increase of fat thickness (about 2 mm), and higher increase of the longest back muscle height (about 5mm), however the increase of carcass weight from 80.0 to 90.0 kg, influenced greater increase of fat thickness (about 5 mm), and smaller increase of the longest back muscle (about 2 mm). In the classification system, where one takes into account fat thickness and the longest back muscle height when estimating the meat percentage, we may expect small decrease of carcass meatiness at carcass weight increase to 85.0 kg, and having exceeded this weight, greater decrease of carcass meat percentage may be expected.

GRUBOŚĆ SŁONINY I POMIARY MIĘŚNIA NAJDŁUŻSZEGO GRZBIETU TUSZ TUCZNIKÓW PODDAWANYCH UBOJOWI PRZY RÓŻNEJ MASIE

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S ł o w a k l u c z o w e: tuczniki, grubość słoniny, pomiary mięśnia najdłuższego grzbietu, różna masa tusz.

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Abstrakt

Badania przeprowadzono na 286 tuszach tuczników wybranych z pogłowia masowego w trzech różnych regionach kraju. Wykonano pomiary grubości słoniny na przepołowieniu tuszy oraz pomiary grubości słoniny i mięśnia najdłuższego grzbietu na dwóch przekrojach polędwicy. Tusze podzielono na trzy grupy, tj. o średniej masie ok. 70, 80 i 90 kg. Badania wykazały, że wzrost masy tusz (tuczników skupowanych przez zakłady mięsne) o ok. 10 kg, spowodował statystycznie istotny wzrost grubości słoniny i wartości pomiarów mięśnia najdłuższego grzbietu we wszystkich badanych punktach. Wzrost masy tusz od 70,0 do 80,0 kg powodował stosunkowo niewielki wzrost grubości słoniny (ok. 2 mm), a większy wzrost wysokości mięśnia najdłuższego grzbietu (ok. 5mm). Wzrost masy tusz od 80,0 do 90,0 kg wpłynął natomiast na większy wzrost grubości słoniny (ok. 5 mm), a mniejszy mięśnia najdłuższego grzbietu (ok. 2 mm). W systemie klasyfikacji, w którym w trakcie określania mięsności tusz bierze się pod uwagę grubość słoniny i wysokość mięśnia najdłuższego grzbietu, można się spodziewać niewielkiego obniżenia mięsności tusz, gdy wzrasta ich masa do 85,0 kg. Po jej przekroczeniu można spodziewać się większego obniżenia mięsności tusz.

Introduction

Optimum carcass weight at which fatteners should be slaughtered is in the centre of interest of pig suppliers as well as meat plants. It is a common knowledge that fatteners of lower weight use smaller amount of feed for 1 kg of gain and have lower slaughter yield factor and higher meat percentage, whereas from fattener carcasses of higher weight we obtain heavier muscles and their meat is more useful as for consumption and processing (BAROWICZ et al. 2006, BUCK 1963, KOĆWIN-PODSIADŁA et al. 2000, ŁYCZYŃSKI et al. 2006, WAJDA 1973, DASZKIEWICZ and WAJDA 2004, Włodawiec 2006). Mostly, these researches were conducted on the fatteners of the chosen breed or cross-bred pigs and they cannot be directly transposed onto mass population. That is why, performing the measurement on the representative sample of fatteners given for slaughter will make it possible to estimate correctly a pricelist of fattener carcass purchase and implementing proper system of rewarding producers for providing meat plants with fatteners of optimum carcass weight.

The objective of this thesis was to define the influence of different carcass weight (70, 80, 90 kg) on fat thickness and the longest back muscle measurements of the fatteners bought by meat plants.

Material and Methods

The research was conducted on 286 carcasses of fatteners which represented mass population of pigs bought in the country. That is why before the choice of carcasses for research was made, the analysis of fat variation level of 14 650 carcasses of fatteners bought by seven meat plants in the different

regions of the country was performed (BORZUTA et al. 2003, GRZEŚKOWIAK et al. 2002). The data gathered in that way enabled to point three ranges of fat cover thickness and was the basis to select such carcasses for the research, which would represent fattener population in the country (WINARSKI 2006). The selection of the carcasses for the research was based on the fat thickness, the equal number of gilt and barrow carcasses and correct division of carcasses into equal half-carcasses. Carcasses for the research originated from raw material background of three meat plants located in different regions of Poland, having different raw material background, i.e.: Ł-Meat in Łuków (93 carcasses), Morliny near Ostróda (62 carcasses), Prime Food in Przechlewo (131 carcasses).

Fattener slaughter was conducted in agreement with regulations of meat industry, and carcasses fulfilled the definition of pig carcass stated in EU regulations (*Council Regulation...* 1984). After about 45 minutes from beginning the bleeding, carcasses were weighed (up to 0,1 kg precision), and after chilling fattener carcasses in Meat Plant in Łuków and Przechlewo they were transported by car coolers to "Morliny" Meat Plant for dissection.

On the left half-carcasses, the following measurement were performed with caliper:

– Fat thickness on the back on the level of last rib,
– Fat thickness over head edge and the centre of *gluteus medius* muscle, i.e. in the so-called points of cross I and cross II.

Half-carcasses were divided into elements according to WALSTRA and MERKUS methodology (1996). After that, loin was cut behind last and between 3rd and 4th thoracic vertebrae, counting from the end of thoracic section of the spine. On obtained cross sections in two points (Figure1), i.e. in the distance of 6 and 7 cm from the division line of the carcass into half-carcasses (so-called points C6 and C7) fat thickness and the longest back muscle height (*m. longissimus dorsi*) was measured. Measurements of height and width of the longest back muscle were the basis to estimate the area of eye of the loin (KIELANOWSKI et al. 1955).

In order to define the influence of carcass weight on the analysed features, the gathered data was divided in the course of statistical calculations into three groups, i.e. carcasses of the weight 60.0 to 76.0 kg (98 carcasses), 76.1 to 85.0 kg (117 pieces.) and over 85.1 kg (71 pieces).

In the statistical calculations, arithmetic mean was taken into account as well as standard deviation for the analysed features, and the significance of statistical differences between the means from the groups with the help of Duncan test. In the statistical calculations, StatSoft STATISTICA software version 7.0 PL was used (ZIELIŃSKI 1999).

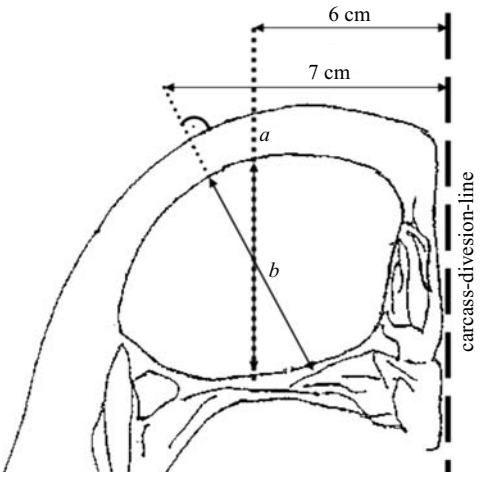

Fig. 1. *Longissimus dorsi* muscle measure points

Results and Discussion

In Poland, just as in most EU countries, classification system EUROP includes into fattener commodity group also gilt and barrow carcass weight of which amounts from 60.0 to 120.0 kg. The initial research (BORZUTA et al. 2003, GRZEŚKOWIAK et al. 2002) showed that the fatteners bought by meat plants usually had the weight between 60.0 to 100.0 kg. Having that on mind, in order to asses the influence of carcass weight on the values of the linear measurements, three ranges were acquired of average carcass weight, i.e. 70, 80 and 90 kg.

The average weight of analysed carcasses was near the assumed one and amounted to 69.80; 80.37 and 90.77 kg, and the difference between means in the analysed groups was about 10 kg (Table 1). The highest variability of carcass weight was found in the group of carcasses of the highest weight (90 kg) and it amounted to 4.75 kg, whereas the smallest variability appeared in the group of carcasses of the weight amounting to 80 kg (2.64 kg). The differences between the means for half-carcass weight were about 5 kg and similar tendency was found for this feature as for weight variability in the analysed groups. Average weight of fattener carcasses included in the own research amounted to 79.33 kg. and was near the average weight of carcasses of fatteners purchased in the country, given by LISIAK and BORZUTA (2003).

Table 1

Carcass weight (kg) and fat thickness measurements (mm)

Specification	Statistics	Carcass weight		
		60.0–76.0 $n=98$	76.1–85.0 $n=117$	85.1–120.0 $n=71$
Hot carcass weight	$\bar{x}$	69.80^{A}	80.37^{B}	90.77^{C}
	s	3.78	2.64	4.75
Half carcass weight	$\bar{x}$	34.12^{A}	39.25^{B}	44.30^{C}
	s	1.90	1.31	2.38
Fat thickness:				
on the back	$\bar{x}$	18.35^{A}	22.09^{B}	26.61^{C}
	s	4.78	5.46	7.00
over cross I	$\bar{x}$	23.15^{A}	24.45^{B}	31.82^{C}
	s	5.47	6.16	6.21
over cross II	$\bar{x}$	15.17^{A}	17.71^{B}	22.62^{C}
	s	4.41	5.73	6.53
on the level of the last thoracic vertebrae*	$\bar{x}$	14.81^{A}	17.26^{B}	22.45^{C}
	s	5.19	6.82	7.88
between 3rd a 4th thoracic vertebrae*	$\bar{x}$	17.08^{A}	20.18^{B}	25.39^{C}
	s	5.75	7.30	7.71
on the level of the last thoracic vertebrae**	$\bar{x}$	13.23^{A}	15.71^{B}	20.31^{C}
	s	4.91	6.38	7.54
between 3rd a 4th thoracic vertebrae**	$\bar{x}$	14.97^{A}	17.86^{B}	22.86^{C}
	s	5.15	6.72	7.38

* – measure performed 6 cm from carcass division line
** – measure performed 7 cm from carcass division line
Means in rows with different letters are significantly different at $p \leq 0.01$ (*A, B, C*)

The main objective of the thesis was to analyze the influence of carcass weight on the measurements of fat thickness and the longest back muscle, which were assessed in the points in which the measurements of carcass meat percentage in EUROP system are performed by the means of ultrasonic or optical-needle probes.

First thing to discuss is the influence of carcass weight on the measurements of fat thickness, performed on the carcass cross section i.e. on the back, on I and II cross (Table 1). The measurement on the back was the basis of the selection of carcasses for research, whereas measurements on I and II cross are the basis to estimate meat percentage of pig carcasses in the EUROP classification system with the help of so-called electronic calipers (BORZUTA 1998). The research proved that the increase of carcass weight is accompanied by the significant increase of fat thickness in all acquired measurement points. Similar growth of fat thickness with the increase of carcass weight was discovered in other research (BUCK 1963, KOĆWIN-PODSIADŁA et al. 2000, ŁYCZYŃSKI et al. 2000, MELLER 1992, WAJDA 1973). Nevertheless, fat thickness in the analysed carcasses was about

1 cm thinner than fat thickness of carcasses of fatteners purchased in the same region of country in 1973 (WAJDA 1973).

Analysing the difference between the means of the examined groups we may find out that fat thickness on the back increased equally with carcass weight increase, whereas fat thickness on cross I and II increased relatively slowly (1.30 to 2.54 mm) with carcass weight increase from 70 to 80 kg, and significantly faster increase of thickness (4.90–7.37mm) is observed with carcass weight increase from 80 to 90 kg. It should also be stated that together with carcass weight increase, the growth of standard deviation value was observed for all analysed fat thickness measurement on carcass cross section.

In the research on fat thickness measurement usefulness for carcass meat percentage estimation it was stated that the highest correlations with carcass meatiness are obtained for fat thickness measurements on the loin cross section (WAJDA et al. 2005). In own research on the loin cross section, fat thickness was measured on the level of last thoracic vertebrae and between 3rd and 4th thoracic vertebrae, counting vertebras from the end, and 6 or 7 cm from the half-carcass cross line (Table 1). In those places, in order to assess meat percentage according to EUROP classification system, fat thickness is usually measured with optical needle and ultrasonic probe. The data shows that, together with the growth of carcass weight, fat thickness increased significantly in those points, and, as in the case of fat thickness measurements on cross I and II, the increase of fat thickness was lower with carcass weight growth from 70 to 80 kg, and over twice as big with carcass weight increase from 80 to 90 kg.

Apart from fat thickness measurements according to EUROP classification system, the measurements of cross section of the longest back muscle are also used, as they are regarded to be as a good indicator of carcass meatiness (WAJDA et al., 2004). In the post-slaughter classification system EUROP (BORZUTA 1998, LISIAK 2002), the measurements of this muscle height which were taken into account, were performed in the same measurement places as fat thickness measurement. The research proved that the values of the measurements of the longest back muscle thickness significantly increased together with the growth of carcass weight (Table 2). Also, together with carcass weight growth we can observe a significant increase of measurement values for the longest back muscle width and eye of loin area. It should be added as well that the increase of "eye" of loin area measurements was higher in the case of carcass weight growth from 70 to 80 kg than at carcass weight growth from 80 to 90 kg. The results (Table 1, Table 2) prove that carcass meatiness estimated on the basis fat thickness and the longest back muscle

measurements decreases relatively slowly together with the increase of their weight in the case of carcass weight up to 85 kg, whereas above this level, fat thickness increases faster and the growth of the longest back muscle height is lower.

Table 2

Longissimus dorsi muscle measurements (mm)

Specification	Statistics	Carcass weight		
		60.0–76.0 $n=98$	76.1–85.0 $n=117$	85.1–120.0 $n=71$
LD muscle height:				
on the level of the last thoracic	$\bar{x}$	53.08^{A}	58.78^{Bb}	60.85^{Cc}
vertebrae*	s	8.63	8.07	8.25
between 3rd a 4th thoracic vertebrae*	$\bar{x}$	47.65^{A}	53.44^{Bb}	55.14^{Cc}
	s	7.81	7.10	7.19
on the level of the last thoracic	$\bar{x}$	55.33^{A}	60.78^{Bb}	62.44^{Cc}
vertebrae**	s	9.64	7.83	6.86
between 3rda 4th thoracic vertebrae**	$\bar{x}$	50.14^{A}	56.73^{Bb}	58.03^{Cc}
	s	8.49	8.04	7.26
LD muscle width:				
on the level of the last thoracic	$\bar{x}$	91.67^{A}	95.73^{Bb}	97.48^{Cc}
vertebrae*	s	6.14	6.31	8.45
between 3rd a 4th thoracic vertebrae*	$\bar{x}$	90.03^{A}	94.35^{B}	96.46^{C}
	s	6.18	6.27	6.35
Eye of loin area (cm^2)				
on the level of the last thoracic	$\bar{x}$	39.20^{A}	45.22^{B}	47.75^{C}
vertebrae*	s	8.34	8.20	9.41
between 3rd a 4th thoracicvertabrae*	$\bar{x}$	34.58^{A}	40.5^{B}	42.76^{C}
	s	7.62	7.29	7.43
on the level of the last thoracic	$\bar{x}$	40.83^{A}	46.70^{Bb}	48.91^{Cc}
vertebrae**	s	8.80	7.81	8.08
between 3rd a 4th thoracic vertebrae**	$\bar{x}$	36.34^{A}	42.97^{Bb}	44.95^{Cc}
	s	7.83	7.61	7.44

* – measure performed 6 cm from carcass division line

** – measure performed 7 cm from carcass division line

Means in rows with different letters are significantly different at $p \leq 0.01$ (*A, B, C*) and $p \leq 0.05$ (*b, c*)

Conclusions

1. The increase of carcass weight of fatteners bought by meat plants by about 10 kg (i.e. from the weight from 70.0 to 80.0 kg and from 80.0 to 90,0 kg) caused statistically significant increase of fat thickness and the longest back muscle measurement value in all examined points.

2. The increase of carcass weight from 70.0 to 80.0 kg resulted in relatively small increase of fat thickness (about 2 mm), and higher increase of the longest back muscle height (about 5 mm), whereas the growth of carcass weight from

80.0 kg to 90.0 kg influenced the higher increase of fat thickness (about 5 mm) and smaller growth of the longest back muscle (about 2 mm).

3. In the classification system, where one takes into account fat thickness and the longest back muscle when estimating meat percentage, one may expect a slight decrease of meatiness with the growth of carcass weight to do 85.0 kg, and over this weight, higher decrease of the carcass meat percentage may be expected.

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TECHNOLOGICAL VALUE OF SELECTED POLISH VARIETIES OF RAPESEED*

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K e y w o r d s: rapeseeds, varieties, technological value of seeds, oil quality.

A b s t r a c t

The objective of the study was to evaluate the technological value of double-improved Polish varieties of rape, i.e. two winter varieties: pollinated variety Kana and hybrid variety Pomorzanin, and one spring variety pollinated Bios. The technological values of seeds and the quality of oils were evaluated by determining their traits which are important in processing and nutrition, i.e.: 1000 seeds mass, geometric features of seeds, contents of oil, phosphorus, phenolic compounds and glucosinolates in seeds, pressing yield, lipid composition, degree of hydrolysis and oxidation of oil as well as contents of total phosphorus and non-hydratable phosphorus. Analyses demonstrated that seeds of the winter variety (Kana, Pomorzanin) were characterized by a higher technological value than those of the spring variety (Bios) due to a higher mass of 1000 seeds and oil content and a lower concentration of phosphorus compounds, including non-hydratable phospholipids. The highest nutritive value was demonstrated for oil processed from seeds of the winter hybrid variety Pomorzanin as it was characterized by the most optimal ratios of n-6 and n-3 acids. The least valuable raw material for the production of edible oil turned out to be seeds of the spring pollinated variety Bios which characterized by the lowest content of oil and, simultaneously, the highest content of non-hydratable phospholipids and unfavorable to health ratio of monounsaturated fatty acids.

WARTOŚĆ TECHNOLOGICZNA NASION WYBRANYCH KRAJOWYCH ODMIAN RZEPAKU

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A b s t r a k t

Celem badań była ocena wartości technologicznej nasion podwójnie ulepszonych krajowych odmian rzepaku: dwóch ozimych – populacyjnej Kana i mieszańcowej Pomorzanin oraz jarej populacyjnej Bios. Wartość technologiczną nasion i jakość olejów oceniano, określając ważne w przetwórstwie i żywieniu cechy, takie jak: masa 1000 nasion i ich wymiary geometryczne, zawartość tłuszczu, fosforu, związków fenolowych i glukozynolanów, wydajność tłoczenia oraz skład lipidowy, stopień hydrolizy i utlenienia oleju oraz zawartość fosforu ogółem i niehydratowalnego. Stwierdzono, że nasiona odmian ozimych (Kana, Pomorzanin) cechowały się wyższą wartością technologiczną od nasion odmiany jarej (Bios), z uwagi na większą masę 1000 nasion i zawartość tłuszczu oraz mniejszą zawartość związków fosforu, w tym fosfolipidów niehydratowalnych. Najwyższą wartość żywieniową miał olej z nasion ozimej odmiany mieszańcowej Pomorzanin, ponieważ zawierał najbardziej optymalne proporcje kwasów n-6 i n-3. Najmniej cennym surowcem do produkcji oleju jadalnego okazały się nasiona populacyjnej odmiany rzepaku jarego Bios. Zawierały najmniej tłuszczu i miały równocześnie najwyższą zawartość fosfolipidów niehydratowalnych oraz niekorzystną dla zdrowia proporcję kwasów wielonienasyconych.

Introduction

Double-improved rape, i.e. erucic acid-free and low-glucosinolate rape, referred to as "canola" was created in Canada in 1974 (SHAHIDI 1990). In Poland, the first double-improved variety was created in the year 1978. Since 1992, only double-improved varieties of rape have been cultivated in Poland. Currently, the National Register of Varieties in Poland includes 66 winter varieties and 19 spring varieties of rape, both pollinated and hybrid ones (*Lista...* 2008).

The agricultural value of rape is determined in post-register variety experiments and is determined by such indicators as: resistance to diseases and lodging, number of seeds in silique, seed yield, mass of 1000 seeds as well as contents of oil, protein, dietary fibre and glucosinolates in the seeds (*Wyniki...* 2008). The agricultural value of varieties is consistent with the technological standard of seeds for processing (*Rośliny...* PN-90/R-66151) only in respect of glucosinolate contents. The technological standard of rape seeds for processing also includes the acid value of oil, content of impurities: useful, useless and mites as well as concentration of erucic acid. Scientific studies have confirmed the importance of all the above-mentioned indicators and have shown that the evaluation of the technological value of rape seeds should be completed with new indicators significant to storage, processing and nutrition, i.e. sizes of seeds, resistance to mechanical damage, lipid composition of oil with consideration given to ratios of polar and non-polar lipids, n-6 and n-3 fatty acids as well as hydratable and non-hydratable phosphorus compounds (SZWED et al. 1995, PŁATEK 1996, 1998, ROTKIEWICZ et al. 2002, ACHREMOWICZ, SZARY-SWORST 2005, TAŃSKA et al. 2008).

Studies conducted on various pollinated varieties indicate significant differences in their agricultural and technological values (MIŃKOWSKI, KRYGIER 1998, NOGALA-KAŁUCKA et al. 2002, ROTKIEWICZ et al. 2002, *Lista...* 2008, *Wyniki...* 2008).

Recently, hybrid varieties, whose high yield is determined by the effect of heterosis, have also been introduced into cultivation practice (BARTKOWIAK-BRODA 1998). Due to their higher yield (by ca. 6–10%) (*Wyniki...* 2008), they may be expected to predominate the pollinated varieties in the future. The agricultural value of hybrid varieties of rape has already been determined (*Lista...* 2008, *Wyniki...* 2008), yet research is lacking on their technological value. With this in mind, the objective of the reported study was to evaluate the technological value of a winter hybrid varieties of rape compared to that of two selected pollinated varieties, a winter and a spring one.

Material and Methods

The experimental material were seeds of three varieties of rape: winter hybrid variety Pomorzanin, winter pollinated variety Kana and spring pollinated variety Bios, originating from the harvest of 2007. The seeds were obtained from the Plant Breeding Station in Strzelce. Selection of varieties was incidental. In these study was important the evaluation of chemical composition of seeds of pollinated and hybrid rape varieties belonging to winter and spring forms.

The technological value of rape seeds was determined based on:

– the mass of 1000 seeds determined by weighing of 100 seeds separated from sample, geometric sizes of seeds assayed with the method of Digital Image Analysis (TAŃSKA et al. 2005),

– content of unripe seeds determined acc. to *Rośliny...* PN-90/R-66145,

– oil content determined acc. to *Nasiona...* PN-EN ISO 659:1999,

– phosphorus content determined with the method with ammonium vanadium acc. to *Rośliny...* PN-88/A-86930,

– content of phenolic compounds assayed with the spectrophotometric method as described by RIBEREAU-GAYON (1972),

– content of glucosinolates assayed with the glucose method as described by HEANEY et al. (1988), and

– contents of non-polar and polar lipids (glyco- and phospholipids) – by means of column chromatography as described by BEKES et al. (1983) with modifications by FENYVESI-SIMON et al. (1992).

Fraction composition was determined with the use of lipids extracted from the seeds according to the method of FOLCH (FOLCH et al. 1957). Pressing yield

was determined as the percentage of the mass of oil pressed from seeds to the mass of oil extracted with petroleum benzine in SOXHLET'S apparatus acc. to *Nasiona...* PN-EN ISO 659:1999. Whole seeds were cold-pressed using a screw oil expeller featuring a cylindrical perforated strainer basket (Komet laboratory CA 59 G). Mechanical impurities were removed from the pressed oil by centrifugation at 10,000 rpm.

The quality of oils, cold-pressed as specified above, was evaluated by assaying: acid value acc. to *Oleje...* PN-ISO 660:1998, peroxide value acc. to *Oleje i tłuszcze...* PN-ISO 3960:1996, anizidine value acc. to *Tłuszcze...* PN-93/A-86926, and fatty acid composition acc. to *Analiza...* PN-EN-ISO-5508:1996, in methyl esters prepared according to the method described by ZADERNOWSKI and SOSULSKI (1978). The contents of total and non-hydratable phosphorus were determined in oils extracted from roasted (1 hour, 100°C) seed pulp with the above-mentioned method.

Results and Discussion

Values of the mass of 1000 seeds determined for the investigated varieties of rape were found to differ. The highest mass of 1000 seeds (6.76 g) was recorded for the hybrid variety Pomorzanin (Table 1). It was higher by 1.68 g than that assayed for the winter pollinated variety Kana and by 2.53 g than that assayed for the spring pollinated variety Bios. Results of post-register variety studies (*Wyniki...* 2008) indicate that the mean mass of 1000 seeds of rape variety Pomorzanin from the harvest of 2007 accounted for 6.2 g, whereas that of the other hybrid varieties – for 3.8–7.6 g.

Table 1

Discriminates of rapeseed technological value

Discriminate	Winter varieties		Spring variety
	Kana	Pomorzanin	Bios
Diameter of seeds (mm)	2.147 ± 0.09	2.359 ± 0.16	2.09 ± 0.11
Area of seeds (mm^2)	3.63 ± 0.31	4.39 ± 0.58	3.44 ± 0.36
Circularity (–)	0.98 ± 0.01	0.96 ± 0.02	0.96 ± 0.03
Mass of 1000 seeds (g)	5.08 ± 0.14	6.76 ± 0.21	4.23 ± 0.12
Oil content (% s.m.)	43.55 ± 0.39	42.10 ± 0.04	39.02 ± 0.08
Glucosinolates (μmol/g smb)	11.31 ± 0.015	11.58 ± 0.020	8.66 ± 0.017
Phenolic compounds (% s.m.)	6.35 ± 0.017	5.60 ± 0.019	4.96 ± 0.021
Yield of pressing (%)	75.4 ± 0.83	73.2 ± 0.76	72.8 ± 0.66
Phosphorus content (mg/kg)	5617 ± 66.5	6261 ± 60.4	6429 ± 58.7
Seed lipids composition (%):			
non-polar lipids	96.94 ± 2.3	97.08 ± 2.8	96.09 ± 2.8
glicolipids	1.15 ± 0.082	0.73 ± 0.043	1.26 ± 0.059
phospholipids	1.91 ± 0.106	2.19 ± 0.113	2.65 ± 0.141

In the case of seeds of the winter pollinated varieties harvested in the same year, the mass of 1000 seeds ranged from 3.7 to 5.6 g, whereas in those of the spring pollinated varieties it ranged from 2.6 to 5.4 g (*Wyniki*... 2008). These values indicate that the mass of 1000 seeds is mainly determined by the form of variety (pollinated, hybrid, winter, spring), and within the variety – by its type. Apart from the variety-specific factor, variability in the mass of 1000 seeds is a result of agroclimatic conditions of the crop (NIEWIADOMSKI 1983, JENSEN et al. 1995, MIŃKOWSKI 1998).

The values of the mass of 1000 seeds displayed a simple correlation with sizes of seeds, i.e. with their diameter and surface area, but were not correlated with the value of a circularity index (Table 1) which distinguished seeds of Kana variety whose plane projection most resembled a circle.

The analyzed samples of seeds did not contain any useless impurities, whereas out of the useful impurities – only unripe seeds that were specified in Table 1. A sample of the hybrid variety Pomorzanin was demonstrated not to contain any unripe seeds, whereas samples of rape of the pollinated varieties Bios (spring) and Kana (winter) were characterized by a high content of unripe seeds, accounting for 2.21 and 1.9%, respectively (Table 1). The technological standard (*Rośliny*... PN-90/R-66151) stipulates that seed bulk of rape designed for purchase and delivery for processing should not contain more than 2% of unripe and sprouted seeds in total.

The oil content of the seeds of the varieties analyzed was relatively diversified, reaching from 39.02% in seeds of the spring pollinated variety Bios to 43.55% in seeds of the winter pollinated variety Kana. In seeds of Pomorzanin variety, the content of oil was average and reached 42.10% (Table 1). In turn, the mean content of oil determined in nation-wide variety investigations for rapeseeds of Pomorzanin and Bios variety harvested in 2007 accounted for 44.0 and 42.3%, respectively (*Wyniki*... 2008), i.e. was higher by ca. 2%. Seeds of winter pollinated and hybrid varieties of rape originating from harvests of 2004–2007 and cultivated under conditions of variety-specific experiments, contained 44–46% of oil on average, whereas in seeds of the spring varieties the oil content was lower by ca. 2–3% (*Wyniki*... 2006, *Wyniki*... 2008). The above-cited results, as well as research conducted on seeds of Polish varieties of winter rape cultivated in the years 1998–2008, point to a little-diversified range of oil content not exceeding 2% (MIŃKOWSKI 1998, MIŃKOWSKI, KRYGIER 1998, BANASZKIEWICZ et al. 2006, *Wyniki*... 2006, *Wyniki*... 2008).

Seeds of the winter rape varieties Pomorzanin and Kana were shown to be characterized by a similar content of glucosinolates, i.e. 11.5 μmol g^{-1} defatted d.m. on average. In turn, in seeds of the spring rape variety Bios the content of glucosinolates was lower by 25% (Table 1). These values confirm data

obtained in the post-register studies, indicating that the seeds of spring varieties exhibit a lower content of glucosinolates (*Wyniki...* 2008). The total content of glucosinolates demonstrated in seeds of the analyzed rape varieties is very low, as it constitutes barely 50% of the admissible level of alkenyl glucosinolates stipulated in the standard (*Rośliny...* PN-90/R-66151), reaching 25 μmol g^{-1} defatted d.m. Alkenyl glucosinolates constitute on average half the total glucosinolates and products of their hydrolysis are detrimental constituents of meal/pomace and oil (SØRENSEN 1990). Isothiocyanates occurring in oils give them an unpleasant aroma and are toxic to hydrogenation catalysts (NIEWIADOMSKI 1993).

In seeds of the investigated rape varieties, the total content of phenolic compounds ranged from 4.96% d.m. (Bios) to 6.35% d.m. (Kana) – Table 1. Phenolic compounds of rapeseeds are perceived as anti-nutrients. Their predominating compound is sinapin (an ester of choline and sinapic acid) that constitutes ca. 90% of all phenolic compounds occurring in rapeseeds (ROTKIEWICZ et al. 1976, ZADERNOWSKI 1987). Sinapin is a bitter compound that diminished palatability of rape fodder and the biological value of protein (ZADERNOWSKI 1987, KOZŁOWSKA et al. 1990).

The oil pressing yield of the seeds of the investigated rape varieties ranged from 72.8% (Bios) to 75.4% (Kana) – Table 1. Pressing yield, especially that of cold-pressing, is an important indicator of the technological value of rape seeds. A higher pressing yield is typical of greater seeds that are characterized by a higher contribution of endosperm (cotyledons + radicle), containing more oil than the seed coat (ZADERNOWSKI et al. 1993, ROTKIEWICZ et al. 2002). Cotyledons of seeds of greater sizes are more susceptible to disintegration as they require less work input necessary to damage their cellular structure (TAŃSKA et al. 2008).

In seeds of the analyzed rape varieties, the total content of phosphorus followed the order: Bios > Pomorzanin > Kana (Table 1). In ripe rape seeds, the predominating form of phosphorus compounds were phytins, constituting 60–90% of total phosphorus acknowledged as anti-nutritional constituents of the non-lipid fraction of seeds (THOMPSON 1990, ROTKIEWICZ et al. 1999, TROSZYŃSKA 2004).

The composition of the lipid fraction of rape seeds was predominated by non-polar lipids which in seeds of the winter rape varieties, i.e. Pomorzanin and Kana, constituted ca. 97% of total lipids, whereas in seeds of the spring variety Bios – 96% (Table 1). In seeds of the later varieties, the highest percentage was noted for polar lipids, glyco and phospho-lipids, which together constituted 3.91% of total lipids. The lowest percentage of polar lipids (2.82%) was determined in seeds of the hybrid variety Pomorzanin. This was mainly due to the lowest content of glycolipids in respect of all varieties examined.

The ratios of non-polar to polar lipids are an important indicator, but have not yet been applied in the evaluation of the technological value of seeds. A higher technological value is attributed to seeds with the highest possible content of the non-polar fraction constituted by triacylglycerols. In turn, the non-triacylglycerol constituents of oil, predominated by polar phospholipids, have to be removed in refining processes as they deteriorate the quality and shelf life of oil (NIEWIADOMSKI 1993, PŁATEK 1996, 1998, ROTKIEWICZ et al. 1998).

The degree of hydrolysis and oxidation of oils pressed from seeds of the investigated varieties of rape was low. The acid value of oils pressed from rape seeds of Pomorzanin and Bios varieties did not exceed 0.50 mg KOH/g oil, and that of oils prepared from Kana variety was 0.70 mg KOH/g oil (Table 2). Such a low of degree of oil hydrolysis in the analyzed seeds results from both the high quality of the seeds (fresh, ripe, pure) and cold-pressing of oil. Industrial seed bulk of rape is usually characterized by a higher degree of oil hydrolysis. According to the Polish quality standard (*Rośliny*... PN-90/R-66145), the acid value of rape seeds designed for processing should not exceed 3 mg KOH/g oil. In edible cold-pressed oil, the admissible level of the acid value is higher and accounts for 4 mg KOH/g oil (*Tłuszcze*... ZN-94/SGO-01), whereas in refined edible oils it accounts for 0.3 mg KOH/g oil (*Oleje*... PN-86908:2000).

The peroxide value of oils pressed from seeds of the investigated varieties of rape ranged from 0.80 to 0.92 mEq O_2/kg oils, thus indicating a very low degree of oil oxidation (Table 2). In cold-pressed oils, the admissible level of the peroxide value reaches 10 mEq O_2/kg oil (*Tłuszcze*... ZN-94/SGO-01), whereas in refined oils it reaches 5 mEq O_2/kg oil (*Rośliny*... PN-90/R-66145).

Table 2

The chemical characteristic of rapeseeds oil

Discriminate	Winter varieties		Spring variety
	Kana	Pomorzanin	Bios
Acid value (mg KOH/g oil)	0.67 ± 0.00	0.50 ±0.08	0.45 ± 0.00
Peroxide value (mEq O_2/kg oil)	0.92 ± 0.01	0.80 ± 0.09	0.88 ± 0.01
Anisidine value	0.1 ± 0.0	0.1 ± 0.0	0.7 ± 0.0
Total phosphour content (mg/kg oil)	434 ± 31.1	441 ± 29.1	476 ± 26.8
non-hydratable (mg/kg oil)	183 ± 16.1	218 ± 20.3	214 ± 10.6
The share of fatty acid (%)			
palmitic acid	4.88	5.06	4.65
stearic acid	1.89	1.91	1.92
oleic acid	62.32	65.05	59.94
linoleic acid	19.17	18.47	19.87
linolenic acid	9.40	7.10	10.83
eicosanoic acid	1.26	1.17	1.46
erucic acid	ślady	ślady	ślady
Relation between acids n-6 : n-3	2.04:1	2.60:1	1.83:1

In turn, the anisidine value – determining the content of secondary products of oxidation (JEŻEWSKA 1991) – of the analyzed oils fluctuated between 0.1 (Pomorzanin and Kana) and 0.7 (Bios), which points to barely initiation of the oxidation processes (Table 2). The significance of that indicator in the evaluation of an oxidation degree of lipids has recently been appreciated, thereby it has been introduced into the qualitative standard of refined oils. The highest admissible value of this indicator has been stipulated at a level of 8 (*Rośliny...* PN-90/R-66145).

The total content of phosphorus compounds in oils, extracted from rapeseed comminuted and roasted under laboratory conditions, ranged from 434 to 476 mg/kg oil. Literature data indicate that industrial pressed oils contain 125–277 mg/kg, whereas the extracted oils contain from 300 to 1190 mg of phosphorus/kg oil (NIEWIADOMSKI 1993, PŁATEK 1998, ROTKIEWICZ et al. 1998).

In oils, the major phosphorus compounds are phospholipids, being structural lipids. They are the main constituents of biological membranes in a seed cell, in which they constitute the membranes of all cellular organelles, including spherosomes (ROTKIEWICZ et al. 2000a). During seed processing, as a result of mechanical and/or thermal degradation of membranes, phospholipids released from them are dissolved in oil (NIEWIADOMSKI 1993, ROTKIEWICZ et al. 2002). They are the cause of turbidity and sediments appearing in oil which impair the course of some refining and modifying processes, hydrogenation and esterification in particular (NIEWIADOMSKI 1993, SHAHIDI 1990).

From the technological point of view, phospholipids are divided into hydratable and non-hydratable ones (PRZYBYLSKI, ESKIN 1991). The first are easily-removable in the hydration process, whereas the latter require the application of acids, thus forming sparingly-utilizable sewage (NIEWIADOMSKI 1993). The non-hydratable phospholipids are likely to constitute 30–40% of total phospholipids, depending on the quality of raw material, technology of production and storage of crude oil (ROTKIEWICZ et al. 1999). In oils pressed from seeds of the analyzed varieties of rape, the percentage of non-hydratable phosphorus ranged from 30% in oil from rape seeds of Pomorzanin variety to 36% in oil from rape seeds of Bios variety, which corresponded to phosphorus contents of 132 and 171 mg/kg oil, respectively (Table 2).

In terms of the contribution of fatty acids, the pollinated varieties (Kana and Bios) were similar, whereas the variety Pomorzanin was found to be different. In oil pressed from seeds of this variety, the concentration of oleic acid was the highest (65.05%), whereas concentrations of linoleic and linolenic acids were the lowest (18.47% and 7.10%, respectively), (Table 2). Oils produced from the pollinated varieties, i.e. winter Kana and spring Bios, were characterized by a similar concentration of linoleic oil, and by various

concentrations of oleic and linolenic acids. Oil from seeds of the spring variety was characterized by the highest concentration of linolenic acid (higher by 3.73% than oil from seeds of variety Pomorzanin) and the lowest concentration of oleic acid (lower by 5.11% than oil from variety Pomorzanin). All the analyzed oils were found to contain trace amounts of erucic acid (Table 2).

The nutritive value of lipids is determined by the linoleic:linolenic acid ratio. According to literature data, the ratio should range from 3:1 to 5:1 (ACHREMOWICZ, SZARY-SWORST 2005). All the oils of the varieties examined, the most similar value to the optimal ratio of those acids reaching 2.6:1 was found for oil from rape seeds of variety Pomorzanin (Table 2).

Conclusions

1. The three analyzed varieties of rape, higher technological values were reported for the winter varieties: pollinated Kana and hybrid Pomorzanin. Their seeds were riper than the seeds of spring variety Bios, contained fewer phosphorus compounds and were more oil-susceptible to pressing than a lower concentration of non-hydratable phospholipids.

2. The lowest technological value was found for seeds of the pollinated spring variety Bios. They were the smallest, contained the highest concentration of phosphorus compounds and had the lowest concentration of oil with the highest contribution of non-hydratable phospholipids.

3. Owing to the optimal ratio of n-6 to n-3 acids, the highest nutritive value was ascribed to oil pressed from rape seeds of hybrid variety Pomorzanin.

4. In a breeding of new varieties of rape one should take into consideration such discriminates as: content and proportions of hydratable and nonhydratable phospholipids and proportions of n-6 and n-3 acids.

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