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ORIGINAL PAPER

Quality of winter rape seeds (*Brassica napus* L.) depending on the genetic factor and on soil and foliar applications of mineral and organic substances*

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Abstract

The research was carried out at the Zawady Agricultural Experimental Station, Poland, in 2018-2021. The experiment was performed with three repetitions in a split-plot system. The factors of the experiment were three morphotypes of winter oilseed rape: population, long-stemmed, semi-dwarf. The second factor consisted of the following preparations or the lack thereof: 1) control, 2) soil conditioner, 3) inorganic biostimulator containing PK, 4) Si biostimulant (plant resistant biostimulant). The aim was to investigate whether the use of soil preparations containing microorganisms and micro- and macro--elements or the foliar application of stimulants containing phosphorus, potassium and silicon would have a better effect on the quality of seeds, i.e.: total protein, crude fat and crude fibre of three different morphotypes of winter oilseed rape. The research showed that the highest concentration of total protein and crude fat was found in the semi-dwarf heterosis morphotype, while the population form had the highest content of crude fibre. In all tested cultivars, after the application of preparations containing potassium and phosphorus and on objects where silicon was used, there was a significant decrease in the protein concentration. The research has shown that the best feed and utility value of seeds was obtained in areas where phosphorus and potassium had been applied in a foliar manner. However, in the case of the traditional variety and the long-stemmed hybrid, the differences in the fat content were statistically insignificant in all objects with biostimulating preparations, while in the case of the semi-dwarf hybrid, this tendency was demonstrated only in the objects with the organic and silicon-containing preparations. All of the tested cultivars were distinguished by the highest concentration of total protein, fat and crude fibre as well as fibre in the season with the lowest annual rainfall.

Keywords: cultivar, resistant biostimulant, silicon, foliar treatment, soil conditioner, protein, fat

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INTRODUCTION

Winter rape *(Brassica napus* L.) is considered to be the most widely cultivated oil-protein plant in the world. This plant occupies an important place in the global production of edible oil and is one of the most important sources of protein in animal feed. According to many authors (Fang et al. 2016, Zhang et al. 2017), rapeseed improves soil properties, including its content of nutrients by accumulating beneficial bacteria and fighting diseases. Rapeseed is also an important source of bioenergy, including biodiesel and industrial oil. Currently cultivated varieties are characterized by a low content of erucic acid and glucosinolates.

Wielebski (2009), Podleśna (2014) and Chmura et al. (2016) report that the quality of rapeseed depends on environmental conditions, genotype, and to a lesser extent on the level of agricultural technology. As emphasized by Jarecki et al. (2022), currently used agrotechnical treatments in agriculture should positively affect both the yield and its quality. Many authors (Beres et al. 2019, Rios et al. 2019) emphasize that feeding with foliar and soil preparations is a standard element of agricultural technology, but new preparations and those already used in agricultural practice should be tested in field experiments.

Foliar and soil fertilizers contain trace elements, such as boron (B), iron (Fe), manganese (Mn), molybdenum (Mo), copper (Cu) or zinc (Zn), titanium (Ti) or silicon (Si).

Silicon is not an essential nutrient for most plants, but it is believed to increase resistance to biotic and abiotic stresses, and to improve the quality and yield of agricultural crops. Chen et al. (2016) found that it increases plant tolerance to heavy metals, drought, salinity and nutrient deficiencies. Other authors (Avice, Etienne 2014, Haddad et al. 2018) emphasize that silicon feeding may extend the life of plant leaves, especially when they are grown under stressful conditions, e.g. in the case of agricultural crops such as *Brassica napus* L., characterized by low nitrogen (N) efficiency.

Bybordi and Mamedov (2010), comparing various methods of feeding plants, showed greater effectiveness of foliar application than soil application. However, in their research, they obtained the highest content of protein and crude fat in winter rapeseed seeds as a result of a combination of soil and foliar application of iron and zinc. Gomaa et al. (2015) found that soil fertilization changes the chemical composition of wheat grain to a greater extent than foliar fertilization does. Following the foliar application of boron, Jankowski et al. (2016) showed a significant improvement in the nutritional value of winter rapeseed seeds (crude fat content, fatty acid content), but some deterioration in their feed value (total protein content, acid detergent fibre content, neutral detergent fibre content, quantitative and qualitative composition glucosinolates). Zeidan et al. (2010), Jarecki et al. (2017) observed an increase in the protein content in spring wheat grains

under the influence of foliar feeding, whereas Vratarić et al. (2006) demonstrated an increase in the protein and fat content in soybeans, and Neuhaus et al. (2014) recorded an increase in the protein concentration in broad bean seeds.

Therefore, the research hypothesis was assumed suggesting that preparations of organic and inorganic origin can modify the chemical composition of winter rape seeds. The aim was to investigate whether the use of soil preparations containing microorganisms and micro- and macro-elements or the foliar application of stimulants containing phosphorus, potassium and silicon would have a better effect on the quality of seeds, i.e.: total protein, crude fat and crude fibre of three different morphotypes of winter oilseed rape.

MATERIALS AND METHODS

In 2018-2021, an experiment was carried out at the Zawady Agricultural Experimental Station (Zawady RSD) owned by the University in Siedlce (52°03′N and 22°33′E), in Poland. The experiment was performed with three repetitions in a split-plot system. The factors of the experiment were three morphotypes of winter oilseed rape:

– population morphotype,

– heterosis long-stemmed morphotype,

– heterosis semi-dwarf morphotype.

The morphological characteristics and agronomic features of the studied varieties are presented in Table 1.

Table 1

Morphological and agronomic features of the examined varieties

Cultivars / morphotypes	Chrobry	PT 271	PX 113
	population	heterosis long-stemmed	heterosis semi-dwarf
Frost resistance	very high	very high	very high
Preferred soil	poor-medium	medium-good	poor-medium-good
Initial vigour	optimal	all right	weak
Flowering time	medium-late	medium-early	medium-late
Date of technological maturity	medium-late	medium-early	medium-late
Resistance to lodging	all right	very good	-
Resistance to dusting	-	all right	all right
Scleroderma rot	all right	-	-
Brassica dry rot (Phoma)	all right	-	all right
Black cross	mean	-	-

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The second factor of the experiment consisted of the application of the preparations:

Control (without the application of any preparations).

Soil conditioner applied: I – in autumn before sowing seeds. II – in spring in phase BBCH 21-36, in doses 0.9 dm^3 ha^{-1}.

Inorganic stimulator containing PK applied: I – in autumn in phase BBCH 13-15, II – in spring in phase BBCH 28-30, in doses 1.0 dm^3 ha^{-1}

Si stimulant (plant resistant biostimulant) applied: I – in autumn in phase BBCH 13-15, II – spring in phase BBCH 51, in doses 0.50 dm^3 ha^{-1}.

The chemical composition of the preparations used in the experiment is given in Table 2.

Table 2

Chemical composition of the applied preparations

The preparation	Chemical composition	Concentration
Soil conditioner	N P K Mg Ca S organic substances (d.m.) bacteria *Lactobacillus* pH form	at least 0.20 % (m m^{-1}) at least 0.02 % (m m^{-1}) at least 0.20 % (m m^{-1}) at least 0.01 % (m m^{-1}) at least 0.02 % (m m^{-1}) at least 0.02 % (m m^{-1}) at least 40.0 % (m m^{-1}) at least 6 x $10^{(3)}$ jkt ml^{-1} > 4.0 liquid, suspension
Inorganic stimulator containing PK	P_2O_5 K_2O	13.0% 5.0%
Si stimulant (plant resistant biostimulant)	SiO_2	200 g l^{-1}, 16.5% (m m^{-1})

Soil conditions

The experiment was carried out on soil classified as a Haplic Luvisol, sandy, very good rye soil complex, valuation class IVa (WRBSR, 2014). The pH of the soil was slightly acidic and ranged from 5.68 to 5.92 in the years of research. The soil was characterized by low abundance of assimilable forms of phosphorus and medium assimilability of potassium and magnesium. The characteristics of the soil conditions in individual research seasons are presented in Table 3. The soil was characterized by a low content of available forms of phosphorus (ranging from 70 to 80 mg kg^{-1}) and an average bioavailability of potassium (ranging from 195 to 202 mg kg^{-1}), and magnesium (ranging from 59 to 63 mg kg^{-1}).

The analysis of the chemical properties of the soil was carried out in the laboratory of the Department of Soil Science and Agricultural Chemistry of the University in Siedlce.

Table 3

Characteristics of soil conditions – AES, Poland

Characteristics of soil conditions	Growing season		
	2018-2019	2019-2020	2020-2021
Group	Haplic Luvisol		
Subtype	sandy		
Valuation class	IV a		
The agricultural suitability complex	rye, very good		
Soil reaction (1 mol dm^{-3} KCl)	5.68	5.92	5.75
Total content of elements (g kg^{-1})			
N	0.90	0.95	0.88
P	0.42	0.55	0.50
K	0.62	0.66	0.69
Mg	0.50	0.48	0.49
The content of absorbable forms of elements (mg kg^{-1})			
P	80.0	70.0	73.0
K	195.0	197.0	202.0
Mg	63.0	60.0	59.0

Fertilization

The preceding crop for winter rapeseed in individual years of the study was winter triticale. Before sowing, 40.0 kg P ha^{-1} and 110.0 kg K ha^{-1} and 40.0 kg N ha^{-1} were applied. During autumn growth and development, 21.0 kg N ha^{-1}, 26.4 kg P ha^{-1}, 92.1 kg K ha^{-1}, 34.8 kg S ha^{-1}, 1.2 kg B ha^{-1} were applied. Fertilization doses were supplemented with 55.9 kg ha^{-1} of ammonium nitrate (19 kg N ha^{-1}), 29.6 kg ha^{-1} of triple superphosphate (13.6 kg P ha^{-1}) and 29 kg ha^{-1} of potassium salt (17.9 kg K ha^{-1}). The second nitrogen dose of 100 kg ha^{-1} was applied during the BBCH 28-30 phase using ammonium nitrate at a dose of 255.5 kg ha^{-1} (86.9 kg N ha^{-1}) and ammonium sulphate at a dose of 62.5 kg ha^{-1} (13.1 kg N ha^{-1} + 15 kg S ha^{-1}). The third nitrogen dose of 60 kg ha^{-1} was applied during the BBCH 50 phase using ammonium nitrate at a dose of 176.5 kg ha^{-1} (60 kg N ha^{-1}).

Sowing

The area of one plot for harvest was 18 m^{-2}. Rapeseed seeds in individual years of the study were sown from 10 to 15 August at a spacing of 22.5 cm and a planting density of 45 pcs. per m^{-2}.

Chemical protection

A product containing clomazone and fluazifop-P-butyl was used to control weeds. Pests were controlled three times using a preparation containing thiacloprid and deltamethrin. Fungicide treatments were carried out using

agents with the following active substances: tebuconazole, fluopyram, protioconazole and prochloraz.

Chemical analysis of seeds

Four samples of seeds of each variety were taken for chemical analysis. Samples of winter rape seeds were subjected to chemical analysis for the content of:

– crude fat (g kg^{-1}dm) – the Soxhlet's method,

– total protein (g kg^{-1} dm) – the Kjeldahl's method,

– crude fibre (g kg^{-1} dm) – the Wenden method.

Chemical analyses of seeds were performed in the chemical-technological laboratory of the Experimental Variety Assessment Station in Słupia Wielka.

Statistical analysis

The test results were subjected to an analysis of variance. The significance of the sources of variation was tested with the Fischer-Snedecor *F* test, while the significance of differences at the significance level of α=0.05 between the compared means was assessed by using the Tukey's multiple intervals. Statistical calculations were made according to an algorithm developed in Excel by the authors.

Climatic conditions

The meteorological data show that the highest average rainfall (419.0 mm) and the highest average air temp. (10.1°C) were in the second year of the study (Figure 1). Based on the calculated Selyaninov's hydrothermal coefficient, it was a very wet growing season (K=2.68). In the first growing season,

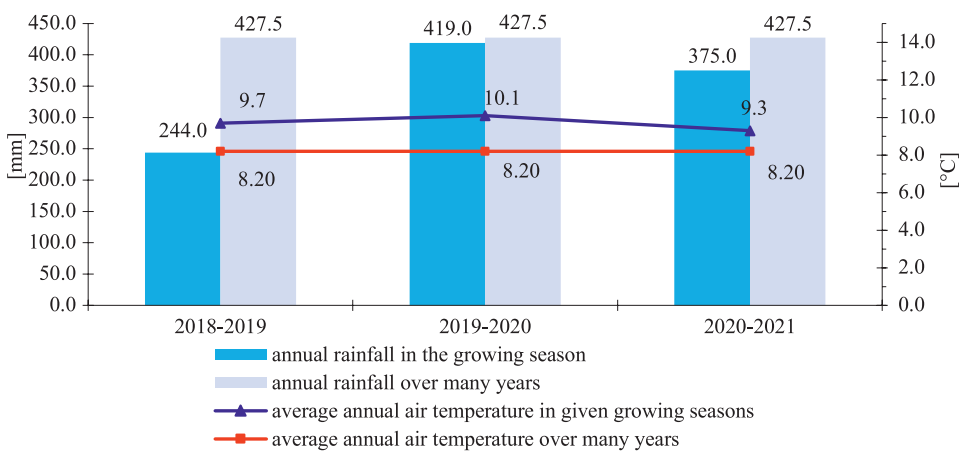

Fig. 1. Monthly precipitation sums and average air temperature in the growing seasons at the Zawady RSD over many years (1996-2010)

the lowest amount of precipitation was recorded (244.0 mm on average), while the average air temp. was 9.7°C. In the third year of the study, the lowest average air temp. was 9.3°C. It was a very wet year (K=2.99) – Figure 2.

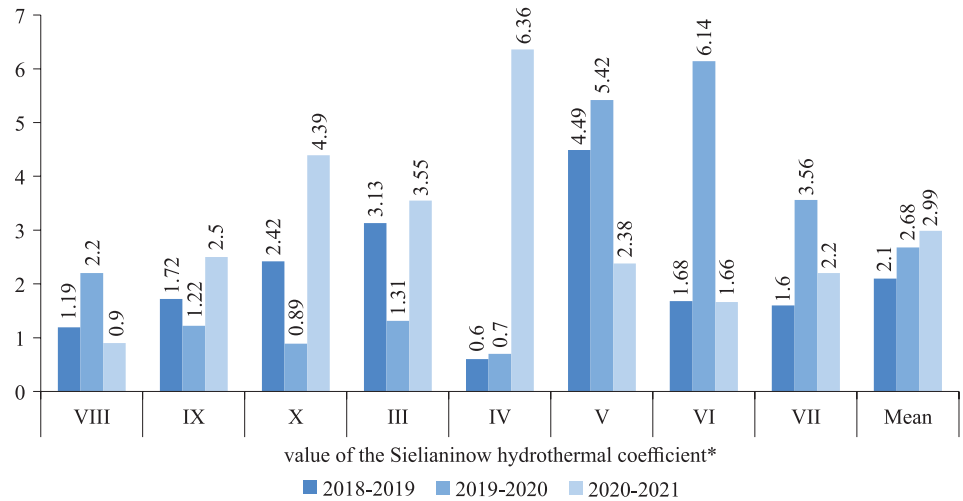

Fig. 2. The value of the Selyaninov hydrothermal coefficient

* Coefficient value according to Skowera (2014): extremely dry (ss) k≤0.4, very dry (bs) 0.4-0.7, dry (s) 0.7-1.0, rather dry (ds) 1.0<k≤1.3, optimal (o) 1.3<k≤1.6, rather wet (dw) 1.6<k≤2.0, wet (w) 2.0<k≤2.5, very wet (bw) 2.5<k≤3.0, extremely wet (sw) k>3.0

RESULTS AND DISCUSSION

Protein content in rape seeds

Based on the research, the highest protein content, 372.97 g kg^{-1} dm on average, was found in seeds of the semi-dwarf hybrid morphotype PX 113. The long-stemmed hybrid variety was characterized by a significantly lower value of this parameter, by 12.06 g on average, and the seeds of the population morphotype had a lower content of this parameter, by 1.93 g kg^{-1} dm on average, compared to the semi-dwarf form (Table 4). A similar tendency was shown by Sikorska et al. (2021). According to the authors, the seeds of the restored hybrids were characterized by a higher protein content compared to the population form. Gugała et al. (2019) also found most protein in seeds of a semi-dwarf form. According to Jarecki (2021), the average total protein content was 226.0 g kg^{-1} dm of seeds. The researcher obtained the highest concentration of the nutrient in seeds of the hybrid variety Visby F1, and a significantly lower amount in the population variety ES Valegro. Other authors (Ratajczak et al. 2017) found no statistically significant differences between the heterosis morphotypes and the population variety, and

Table 4

Chemical composition of rape seeds depending on preparations and tested cultivars

Stimulating preparations (B)	Cultivars (A)			Mean
	Chrobry	PT 271	PX 113	
Total protein (g kg^{-1} dm)				
Object 1	371.42	361.31	373.40	368.71
Object 2	371.49	362.02	373.29	368.94
Object 3	370.52	360.56	372.66	367.91
Object 4	370.74	359.76	372.51	367.67
Mean	371.04	360.91	372.97	-
			$LSD_{0.05}$ for:	
			A	0.68
			B	0.52
			Interaction: *A x B*	0.90
Crude fat (g kg^{-1} dm)				
Object 1	420.88	431.33	437.11	429.77
Object 2	421.68	432.03	438.77	430.83
Object 3	422.10	432.31	439.73	431.38
Object 4	421.80	431.74	438.43	430.66
Mean	421.61	431.86	438.51	-
			$LSD_{0.05}$ for:	
			A	0.35
			B	0.32
			Interaction: *A x B*	0.55
Crude fibre (g kg^{-1} dm)				
Object 1	80.77	76.78	79.41	78.99
Object 2	81.07	77.07	79.80	79.31
Object 3	81.69	77.39	80.38	79.82
Object 4	80.93	76.86	79.62	79.14
Mean	81.11	77.03	79.80	-
			$LSD_{0.05}$ for:	
			A	0.20
			B	0.17
			Interaction: *A x B*	n.s.

Object 1 – control (without the application of preparations), object 2 – soil conditioner, object 3 – inorganic biostimulator containing PK (13.0% of P_2O_5 *and* 5.0% of K_2O), object 4 – Si biostimulant (plant resistant biostimulant)

the average protein content according to Carre et al. (2016) was 382.0 g kg^{-1} on a dry defatted basis.

The types of preparations used affected the protein content in the seeds of the studied morphotypes. Studies have shown that after the use of preparations containing potassium and phosphorus and on objects where silicon

was used, there was a significant decrease in protein concentration, while the differences between these objects were statistically insignificant. After using the preparation with microorganisms, there was no significant increase in the concentration of this parameter compared to the control (Table 4). Sikorska et al. (2021) obtained the highest protein concentration after using a biopreparation containing amino acids. Many authors (Kozak et al. 2010, Matysiak et al. 2011, 2012) Gugała et al. 2019 proved the lack of a significant effect of biostimulating preparations on the protein content in rape seeds. A similar tendency was noted by: Jarecki and Bobrecka-Jamro (2008), Kwiatkowski (2012) and Jankowski et al. (2019) after autumn supplementation with micro and macro elements. Other authors (Jarecki et al. 2022) obtained a significantly higher protein concentration in seeds collected after three applications of a preparation containing 5.8% N and 11.1% B compared to the control object.

Crude fat content in rape seeds

The highest crude fat content in winter rape seeds was found in the semi-dwarf form PX 113, and significantly lower, by an average of 16.9 g kg^{-1} dm, in the population variety Chrobry. The long-stemmed variety contained less fat in seeds by 6.6 g kg^{-1} dm compared to the semi-dwarf variety (Table 4). This trend was confirmed in the research by Gugała et al. (2019) and Sikorska et al. (2021). Oleksy et al. (2019) noted more crude fat in seeds of a heterosis variety. According to Jarecki (2021), the crude fat content in seeds was not differentiated by a variety and averaged 475.0 g kg^{-1} dm. Similar conclusions were reached by Hoppe and Wenda-Piesik (2018), who showed the smallest difference in this feature between the population form (46.5%) and the hybrid form (46.4%). Carre et al. (2016) recorded on average as much as 533.0 g kg^{-1} dm of crude fat in seeds of the studied cultivars.

The cultivars responded differently to the types of applied biostimulators (Table 4). The highest fat content in all tested cultivars, on average from 422.10 to 439.73 g, was found in plants grown on plots where phosphorus and potassium were applied. Regarding the traditional variety and the long-stemmed hybrid, the differences in the fat content were statistically insignificant in all objects treated with biostimulating preparations, while in the case of the semi-dwarf hybrid, this tendency was demonstrated only in the objects with the organic and silicon-containing preparations. Sikorska et al. (2021) obtained the highest increase in the crude fat concentration in seeds after the application of foliar fertilizers containing sulphur, boron and amino acids, and the smallest one – after the application of a biostimulator containing amino acids (object 2). Jankowski et al. (2019) showed an increase in the crude fat content by an average of 1.3 g kg^{-1} dm (one application) and 7.4 g kg^{-1} dm (two applications) under the influence of foliar application of macro- and micronutrients in autumn. On the other hand, Bowszys (2001) showed a decrease in the useful value of seeds after the foliar feeding with

boron at doses of 400, 600, 800, 1200 g B ha^{-1}. Similar results were obtained after intensive foliar fertilization tested by Jankowski et al. (2016), who conducted research in north-eastern Poland. Other authors did not show significant differences in the crude fat content under the influence of foliar fertilizer containing nitrogen and boron (Jarecki et al. 2022).

Crude fibre content in rape seeds

The highest amount of crude fibre was found in the seeds of the population cultivar, significantly less in the semi-dwarf form, and the least in the long-stemmed hybrid (Table 4). Sikorska et al. (2021) showed the highest amount of crude fibre in a semi-dwarf hybrid, and the lowest in a hybrid with a traditional type of union.

The research showed that the highest amount of crude fibre was recorded in the objects where phosphorus and potassium were used, and significantly less in the other objects (Table 4). There was no interaction between the types of preparations used and the cultivars studied. In turn, Jarecki and Bobrecka-Jamro (2008) found that foliar feeding of rapeseed did not significantly affect the content of crude fibre in rape seeds, and in later studies, the authors (Jarecki et al. 2019) found a decrease in fibre content in seeds by an average of 0.6%. under the influence of foliar fertilizers applied in autumn and spring, in autumn and twice in spring, twice in spring. In the following years (Jarecki et al. 2022) it was found that foliar feeding with nitrogen and boron did not significantly affect the crude fibre content.

Chemical composition of seeds depending on climatic conditions

The highest protein content was found in the first year of the study, in which the lowest rainfall was recorded (on average 244.0 mm), and the average air temperature in this growing season was on average 9.7°C. The lowest protein concentration in seeds was found in the second year of the study, which was a very wet season according to the Selyaninov hydrothermal coefficient (Table 5).

The interaction of the varieties with the years of research has also been demonstrated. It should be emphasized that all the tested cultivars were distinguished by the highest concentration of this component in the first year of the study, and the biggest significant difference in the value of this feature in the years of the study was determined for the long-stemmed hybrid.

The study has shown a varied effect of biostimulating preparations in the years of research. In the first year, the same value of the protein content was found on all objects (1-4) of the experiment. In the second year, the use of the organic preparation slightly increased the protein content compared to the control. On the other hand, the use of silicon, phosphorus and potassium decreased the protein content in the second and third year of the study.

The highest fat content in seeds, on average 434.36 g kg^{-1} dm, was found in the season with the lowest annual rainfall. In the second, most humid

Table 5

Chemical composition of rape seeds depending on years of research and cultivars

Years (C) growing season	Cultivars (A) Chrobry	PT 271	PX 113	Mean
Total protein (g kg^{-1} dm)				
2018/2019	373.09	367.93	374.62	371.88
2019/2020	368.92	355.84	371.13	365.29
2020/2021	371.13	358.97	373.16	367.75
Mean	371.04	360.91	372.97	-
			LSD $_{0.05}$ for:	
			A	0.68
			C	0.68
			Interaction: *C x A*	1.18
Crude fat (g kg^{-1} dm)				
2018/2019	426.98	435.33	440.78	434.36
2019/2020	410.43	427.93	432.70	423.69
2020/2021	427.43	432.30	442.06	433.93
Mean	421.61	431.86	438.51	-
			LSD $_{0.05}$ for:	
			A	0.35
			C	0.35
			Interaction: *C x A*	0.61
Crude fibre (g kg^{-1} dm)				
2018/2019	82.19	78.11	80.44	80.25
2019/2020	79.32	75.29	78.98	77.86
2020/2021	81.83	77.68	79.99	79.83
Mean	81.11	77.03	79.80	-
			LSD $_{0.05}$ for:	
			A	0.20
			C	0.20
			Interaction: *C x A*	0.35

year of the study, the value of this feature was significantly lower by an average of 10.7 g kg^{-1} dm compared to the previous growing season. In the 2020-2021 growing season, the average fat content in seeds was 433.93 g kg^{-1} dm (Tables 5, 6).

The effect of biostimulating preparations was dependent on climatic conditions prevailing in the years of research. In the first year, the highest concentration of crude fat was found in all tested objects. The highest value of this feature was shown on the object where the organic preparation was used, while the differences between the 3rd and 4th object were statistically insignificant. In the second and third year, most fat was found in the cultivars grown on the plots where phosphorus and potassium were

Table 6

Chemical composition of rape seeds depending on preparations and years of research

Stimulating preparations (B)	Years (C)			Mean
	2018/2019	2019/2020	2020/2021	
Total protein (g kg^{-1} dm)				
Object 1	372.17	365.08	368.89	368.71
Object 2	372.06	366.66	368.09	368.94
Object 3	372.05	364.02	367.67	367.91
Object 4	371.25	365.42	366.34	367.67
Mean	371.88	365.29	367.75	-
			$LSD_{0.05}$ for:	
			C	0.68
			B	0.52
			Interaction: *C x B*	0.90
Crude fat (g kg^{-1} dm)				
Object 1	433.46	422.79	433.08	429.77
Object 2	435.26	423.38	433.84	430.83
Object 3	434.50	424.70	434.94	431.38
Object 4	434.23	423.89	433.86	430.66
Mean	434.36	423.69	433.93	-
			$LSD_{0.05}$ for:	
			C	0.35
			B	0.31
			Interaction: *C x B*	0.54
Crude fibre (g kg^{-1} dm)				
Object 1	79.91	77.56	79.49	78.99
Object 2	80.30	77.78	79.86	79.31
Object 3	80.81	78.40	80.26	79.82
Object 4	79.97	77.71	79.73	79.14
Mean	80.25	77.86	79.83	-
			$LSD_{0.05}$ for:	
			C	0.30
			B	0.17
			Interaction: *C x B*	n.s.

Object 1 – control (without the application of preparations), object 2 – soil conditioner, object 3 – inorganic biostimulator containing PK (13.0% of P_2O_5 *and* 5.0% of K_2O), object 4 – Si biostimulant (plant resistant biostimulant)

used, while the differences between objects 2 and 4 were statistically insignificant.

The highest amount of crude fibre in all tested varieties was found in the first year of research, with the lowest annual rainfall and the average air

temp. of 9.7°C, while significantly the lowest crude fibre accumulated during the most humid growing season of 2019-2020.

Mączyńska et al. (2015) demonstrated that the crude fat content in oilseed rape seeds was significantly affected by the weather conditions prevailing in individual study years. In their study, the fat content was higher in colder years with higher precipitation than in warm years.

There was no dependence of the applied biostimulating preparations on climatic conditions. There was no interaction of years with the applied biostimulating preparations, meaning that these preparations acted in the same way in each year of the study.

CONCLUSIONS

1. The research showed that the highest concentration of total protein and crude fat was in the semi-dwarf heterosis morphotype, while the population form had the highest content of crude fibre.

2. In all the tested cultivars, after the application of preparations containing potassium and phosphorus and on objects where silicon was used, there was a significant decrease in the protein concentration.

3. Research has shown that the best feed and utility value of seeds was obtained in plots where phosphorus and potassium were applied in a foliar manner. However, the differences in the fat content in the traditional variety and the long-stemmed hybrid were statistically insignificant in all objects treated with biostimulating preparations, while in the case of the semi-dwarf hybrid, this tendency was demonstrated only in the objects enriched with the organic and silicon-containing preparations.

4. All the tested cultivars were distinguished by the highest concentration of total protein, fat and crude fibre as well as fibre in the season with the lowest annual rainfall.

Author contributions

Methodology, M.G.; software – M.G., and K.Z.; conceptualization – A.S., and M.G.; formal analysis – K.Z.; funding acquisition – M.G.; investigation – A.S.; supervision – P.F., M.P.; writing – original draft preparation – A.S.; writing – review & editing – I.M.

Conflicts of interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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