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WINTER OILSEED RAPE YIELD DEPENDING ON FOLIAR FERTILIZATION

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ABSTRACT

Background. An insufficient amount of nutrients in plants results in the disturbance of basic physiological processes, weakens the growth and development of plants, and consequently contributes to a reduction in yield. The aim of this study was to determine the effect of foliar fertilizers containing sulphur, boron and amino acids on the seed yield of three winter oilseed rape morphotypes (Monolit, PX115, PT248).
Material and methods. The study was carried out in 2016-2019 at the Zawady Agricultural Experimental Station (52°03' N; 22°33' E) belonging to the University of Natural Sciences and Humanities in Siedlce, in Poland. The field experiment was established in a split-plot design with three replicates. The studied factors were: I – three winter oilseed rape morphotypes: population (cv. Monolit), restored with the traditional growth type (cv. PT248), and restored with the semi-dwarf growth type (cv. PX115); II – types of foliar feeding: 1. The control variant – without foliar feeding and amino acids applied, 2. biostimulant Aminoplant, 3. foliar fertilizer Siarkomag + foliar fertilizer Bormax, 4. foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulant Aminoplant.
Results. Foliar fertilizers used in the experiment increased the thousand seed weight (on average in the range from 0.9% to 3.4%), seed yield (on average in the range from 2.5% to 18.5%), straw yield (on average in the range from 2.1% to 5.4%) and the harvest index (on average in the range from 4.4% to 7.5%). Of the compared cultivars the semi-dwarf cultivar (PX115) was characterized by the highest yield, while the lowest was from the population cultivar (Monolit). The highest thousand seed weight, main and secondary yields were obtained in the first year of the study which was characterized by a higher total rainfall during seed development and maturation of pods periods compared to the multi-year period, while the lowest levels of these factors was in the vegetation season of 2017–2018 with a humid autumn season and dry period during the flowering and maturation of pods.
Conclusion. The most significant increase in the thousand seed weight and seed yield was obtained after applying mixed fertilizers containing sulphur, boron and amino acids. Additional foliar application of the biostimulant Aminoplant on plots with the population and semi-dwarf cultivars did not significantly increase the seed yield as compared to the control. A significant effect of the genetic factor and climatic conditions on the discussed traits has been demonstrated.

Key words: amino acids, boron, *Brassica napus* L., foliar feeding, harvest index, seed yield, straw yield, sulphur, thousand seed weight

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INTRODUCTION

Insufficient plant nutrition affects basic physiological processes, which adversely affects the growth and development of plants and contributes to a reduction in yield (Kocoń and Grenda, 2004). Kaur *et al.* (2019) emphasize that as a result of foliar nutrition nutrient deficiencies caused by various factors, including variable climatic conditions, intensive plant development, drought, agricultural errors, can be reduced.

Boron is an essential element for the proper growth and development of plants. Bowszys (2001) reports that winter oilseed rape needs boron in the range from 145 to 290 $g \cdot ha^{-1}$. Its deficiency causes the inhibition of the growth and development of roots and of the aboveground parts of plants. Xu *et al.* (2001) found that these changes can even lead to tissue necrosis. Boron is a micronutrient necessary for the production of pollen, which is why winter oilseed rape plants are most sensitive to its deficiency at the flowering stage. Girondė *et al.* (2014) report that winter oilseed rape demand for sulphur ranges from 20 to 30 $kg\ S \cdot ha^{-1}$. Sulphur has a positive effect on the synthesis of chlorophyll and carbohydrates and protein metabolism. Under optimal supply conditions this macronutrient induces an increase in plant resistance to biotic and abiotic stress (Gaj and Klikocka, 2011). Amino acids affect the photosynthesis and respiration of plants and increase the content of unsaturated (oleic) and saturated (linolenic) fatty acids (Long *et al*., 2006; Jakienė, 2013).

The research hypothesis that was adopted in the paper assumes that biostimulants combined with foliar feeding may positively influence the yield of three winter oilseed rape cultivars. The aim of this study was to determine the effect of foliar application of sulphur, boron, amino acids on the seed yield of three winter oilseed rape morphotypes (Monolit, PX115, PT248).

MATERIAL AND METHODS

The study was carried out in 2016–2019 at the Zawady Agricultural Experimental Station (52°03' N; 22°33' E) belonging to the University of Natural Sciences and Humanities in Siedlce, in Poland. The field experiment was established in a split-plot design with three replicates. The area of one plot for harvest was 21 m^2. The studied factors were:

I – three morphotypes of winter oilseed rape:
- a population morphotype (cv. Monolit),
- a restored morphotype with the traditional growth type (cv. PT248),
- a restored morphotype with the semi-dwarf growth type (cv. PX115);

II – types of foliar feeding:
- control – without foliar feeding and amino acids,
- biostimulant Aminoplant 1.0 $dm^3 \cdot ha^{-1}$: in the autumn at 4-6 leaf stage (BBCH 14–16), in the spring after the start of growth (BBCH 28–30), and at the stage of flower bud development (budding) – beginning of flowering (BBCH 50–61),
- foliar fertilizers Siarkomag 2.0 $dm^3 \cdot ha^{-1}$ + Bormax 0.5 $dm^3 \cdot ha^{-1}$: in the autumn at 4–6 leaf stage (BBCH 14–16), in the spring after the start of growth (BBCH 28–30), and at the stage of flower bud development (budding) – beginning of flowering (BBCH 50–61),
- foliar fertilizers Siarkomag 2.0 $dm^3 \cdot ha^{-1}$ + Bormax 0.5 $dm^3 \cdot ha^{-1}$ + biostimulant Aminoplant 1.0 $dm^3 \cdot ha^{-1}$: in the autumn at 4–6 leaf stage (BBCH 14–16), in the spring after the start of growth (BBCH 28–30), and at the stage of flower bud development (budding) – beginning of flowering (BBCH 50–61).

In the growing season 2016–2017 spring wheat was the previous crop for winter oilseed rape, while in 2017–2018 and 2018–2019 it was winter triticale. The experiment was carried out on soil classified according to the World Reference Base for Soil Resources (2014) to the Haplic Luvisol group, sanded, belonging to the very good rye soil complex, of the IVa class. In the years of the experiment the pH (in 1N KCl) of the soil was slightly acidic and ranged from 5.68 to 5.75. The soil was characterized by a low content of available forms of phosphorus (ranging from 75 to 81 $mg \cdot kg^{-1}$) and average bioavailability in potassium (ranging from 199 to 202 $mg \cdot kg^{-1}$) and magnesium (ranging from 59 to 63 $mg \cdot kg^{-1}$) .

After harvesting the previous crop, soil treatment was carried out using a stubble cultivator and a tubular string roller and then two weeks after this first measure pre-sowing ploughing was carried out to a depth of 20 cm while simultaneously using a ring roller. To prepare the soil for sowing and to mix fertilizers a combined tilling unit was used. Before sowing, phosphorus and potassium fertilization was applied at a rate of 40 kg P·ha^{-1} and 110 kg K·ha^{-1} and the first rate of nitrogen at 40 kg N·ha^{-1}. Fertilization under winter oilseed rape was applied in the form of Lubofos at a rate of 600 kg·ha^{-1}, i.e. 21 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}. Fertilization rates were supplemented with 55.9 kg·ha^{-1} ammonium nitrate (19 kg N·ha^{-1}), 29.6 kg·ha^{-1} triple superphosphate (13.6 kg P·ha^{-1}) and 29 kg·ha^{-1} potassium salt (17.9 kg K·ha^{-1}). The second nitrogen rate of 100 kg·ha^{-1} was applied in the spring before the start of growth (BBCH 28-30) using ammonium nitrate at a rate of 255.5 kg·ha^{-1} (86.9 kg N·ha^{-1}) and ammonium sulphate at a rate of 62.5 kg·ha^{-1} (13.1 kg N·ha^{-1} + 15 kg S·ha^{-1}). The third nitrogen rate of 60 kg·ha^{-1} was applied at the beginning of budding (BBCH 50) using ammonium nitrate at a rate of 176.5 kg·ha^{-1} (60 kg N·ha^{-1}).

The sowing of winter oilseed rape was performed with a row spacing of 22.5 cm, assuming a density of 60 pcs·m^{-2}. Sowing was carried out at the optimal date recommended for this region (in 2016 – August 12, 2017 – August 14, and in 2018 – August 13).

Chemical protection against weeds, diseases and pests was used in accordance with the recommendations of good agricultural practice (Table 1). Rapeseed was harvested in two stages in the first twenty days of July.

Table 1. Applied chemical protection (Zawady Agricultural Experimental Station, Poland)

Applied pesticides	Active substance	Developmental stages	acc. to BBCH
		Herbicides	
Command 480 EC in a dose of 0.25 dm^3·ha^{-1}	clomazone	directly after sowing into carefully cultivated soil	00 BBCH
Fusilade Forte 150 EG in a dose of 2.0 dm^3·ha^{-1}	fluazifop-P-butyl	3-4 leaf stage	13-14 BBCH
		Insecticides	
Proteus 110 OD in a dose of 0.6 dm^3·ha^{-1}	thiacloprid deltamethrin	1 application - growth (elongation) of the main stem	30 BBCH
		2 application – flower bud development (budding)	50-58 BBCH
		3 application - flowering	60-69 BBCH
		Fungicides	
Horizon 250 EW in a dose of 0.75 dm^3·ha^{-1}	tebuconazole	winter oilseed rape 4-8 leaf stage	14-18 BBCH
Propulse 250 SE in a dose of 1.0 dm^3·ha^{-1}	fluopyram prothioconazole	start of flowering	61 BBCH
Mondatak 450 EC in a dose of 1.0 dm^3·ha^{-1}	prochloraz	falling stage of first forest petals	65 BBCH

The thousand seed weight was determined from 2 samples each of 500 seeds that were collected from the purified crop from each plot.

The quantity of seed yield from each plot was determined by weight after threshing, and then, after adjusting to normative humidity (9.0% of water content in seeds), calculated per 1 ha.

The value of the harvest index (HI) was calculated according to the formula:

$$\mathrm{HI} = \frac{\mathrm{Pn}}{\mathrm{Pn} + \mathrm{Ps}}$$

where:

HI – harvest index,

Pn – seed yield ($\mathrm{Mg \cdot ha^{-1}}$),

Ps – straw yield ($\mathrm{Mg \cdot ha^{-1}}$).

The study results were statistically analyzed by means of the analysis of variance. The significance of sources of variation was tested with the Fisher--Snedecor F test, and the significance of differences at the significance level P = 0.05 between the compared means was assessed using multiple Tukey intervals. Statistical calculations were made on the basis of our own algorithm written in Excel in accordance with the above mathematical model:

Yijlp = m + ai + gj + e/1/ij + bl + abil + e/2/ijl + cp + acip + bclp + abcilp + e/3/ijlp.

RESULTS AND DISCUSSION

Based on the conducted research it was shown that the thousand seed weight depended significantly on the types of foliar feeding (Table 2). The largest increase in the thousand seed weight, by an average of 3.4% compared to the control variant was found on plots with foliar application of sulphur, boron and the biostimulant with amino acids (treatment 4). Jarecki and Bobrecka-Jamro (2008) showed that under the influence of Basfoliar 12-4-6+S with Solubor DF the difference in thousand seeds weight compared to the control was over 1 g (i.e. 24%). Jankowski *et al.* (2016a), after applying foliar fertilization, found an increase in the value of this trait ranging from 1.3% to 3.8%. The beneficial effect of foliar fertilization with Insol 5 concentrate used in several variants: in autumn and spring, in autumn and double in spring, twice in spring, has been shown by Jarecki *et al.* (2019). However, no significant effect of the foliar fertilization the value of this trait has been reported by El Habbasha and El Salam (2010), Varga *et al.* (2010), Czarnik *et al.* (2015) and Szczepanek *et al.* (2016).

The effect of foliar preparations on seed yield has been presented in studies by many authors. Jarecki and Bobrecka-Jamro (2008) found the best results after feeding plants with Basfoliar 36 Ex plus Solubor DF or with Basfoliar 12-4-6+S plus Solubor DF, with the seed yield increased by an average of 14.1% after their application. Kaur *et al.* (2019) and Pużyńska *et al.* (2018) also noted an increase in seed yield after the application of foliar fertilizers containing sulphur, nitrogen and phosphorus as well as after those containing sulphur and boron. A similar tendency was observed by Szczepanek *et al.* (2016) and Szczepanek and Bech (2019) after using Humistar and/or Drakar and Phostrade BMo. Jankowski *et al.* (2016b), as a result of foliar application of boron, showed an increase in winter rapeseed yield on average from 3% (150 g $\mathrm{B \cdot ha^{-1}}$) to 4% (300 g $\mathrm{B \cdot ha^{-1}}$), and Ma *et al.* (2015) on average from 7 to 13%, while Czarnik *et al.* (2015) after the application of Basfoliar 12-4-6+S + amino on average by 12.3% compared to the control variants. Gugała *et al.* (2019), after using biostimulants containing phenolic compounds: sodium ortho- and para-nitrophenolate and sodium 5-nitrogujacolate (Asahi SL), titanium ions (Titanit) and active silicon (Silvit), also reported a significant increase in seed yield ranging from 2.9% to 8.7% compared to the control.

El-Habbasha and El-Salama (2010), Wójtowicz and Jajor (2010) and Gugała *et al.* (2019) emphasize that heterosis cultivars have a higher yield potential than traditional ones. Of the compared cultivars in this research the restored hybrid with the semi-dwarf growth type (PX 115) was characterized by the highest thousand seed weight and seed yield. The value of these traits was higher by an average of 0.37 grams and 0.42 $\mathrm{Mg \cdot ha^{-1}}$ compared to the population morphotype Monolit. A similar tendency for the thousand seed weight has been recorded by Mekki (2013), Czarnik *et al.* (2015) and Gugała *et al.* (2019).

Table 2. Thousand seed weight, seed yield, straw yield, harvest index depending on types of foliar fertilization

	Foliar feeding types	Cultivars			Mean
		Monolit	PT 248	PX 115	
	Thousand seed weight, g				
1	Control variant	5.32 [a]	5.51 [d]	5.68 [f]	**5.50[a]**
2	Biostimulant Aminoplant	5.35 [a]	5.59 [e]	5.71 [f]	**5.55[b]**
3	Foliar fertilizer Siarkomag + foliar fertilizer Bormax	5.39 [c]	5.69 [f]	5.79 [g.h]	**5.62[c]**
4	Foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulant Aminoplant	5.48 [d]	5.78 [g]	5.82 [h]	**5.69[d]**
	Mean	**5.38[a]**	**5.64[b]**	**5.75[c]**	–
	Seed yield, $Mg \cdot ha^{-1}$				
1	Control variant	2.96	3.18	3.40	**3.18[a]**
2	Biostimulant Aminoplant	3.06	3.23	3.50	**3.26[b]**
3	Foliar fertilizer Siarkomag + foliar fertilizer Bormax	3.38	3.53	3.74	**3.55[c]**
4	Foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulant Aminoplant	3.56	3.75	4.00	**3.77[d]**
	Mean	**3.24[a]**	**3.42[b]**	**3.66[c]**	–
	Straw yield, $Mg \cdot ha^{-1}$				
1	Control variant	5.46 [ab]	5.09 [d]	4.86 [g]	**5.13[a]**
2	Biostimulant Aminoplant	5.40 [a]	5.22 [eh]	5.12 [h]	**5.24[b]**
3	Foliar fertilizer Siarkomag + foliar fertilizer Bormax	5.54 [bc]	5.30 [ef]	5.23 [efh]	**5.36[c]**
4	Foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulant Aminoplant	5.60 [c]	5.35 [f]	5.29 [efh]	**5.41[c]**
	Mean	**5.50[a]**	**5.24[b]**	**5.12[c]**	–
	Harvest index				
1	Control variant	0.352 [a]	0.385 [c]	0.416 [fh]	**0.385[a]**
2	Biostimulant Aminoplant	0.363 [b]	0.384 [c]	0.409 [fg]	**0.385[a]**
3	Foliar fertilizer Siarkomag + foliar fertilizer Bormax	0.382 [c]	0.403 [e]	0.420 [h]	**0.402[b]**
4	Foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulant Aminoplant	0.391 [d]	0.416 [fh]	0.435 [i]	**0.414[c]**
	Mean	**0.372[a]**	**0.397[b]**	**0.420[c]**	–

values marked with the same letter do not differ significantly at $P = 0.05$

The effect of the type of foliar feeding on thousand seed weight depended on genetic factors (Table 2). This study has shown that in the population morphotype (Monolit) and the restored hybrid with the semi-dwarf growth type (PX115) the thousand seed weight after using the biostimulant Aminoplant was the same as it was in their control variants. The population morphotype and the hybrid with the traditional growth type (PT248) had the largest thousand seed weights under treatment 4, where foliar fertilization with sulphur, boron and a biostimulant containing amino acids was used. The use of a biostimulant in combination with foliar feeding in the semi-dwarf hybrid did not significantly increase the value of this trait.

The present author's research has shown a significant effect of foliar feeding types on straw yield (Table 2). It was highest on treatments where foliar feeding with sulphur and boron was applied (treatment 3) and where sulphur, boron and amino acids were applied (treatment 4), with the differences between these treatments being statistically insignificant. This is in line with the results of the studies by Gugała *et al.* (2019), Bowszys and Krauze (2000) and Jankowski *et al.* (2016b), who all claim that intensive foliar fertilization increases the straw yield.

The present author's study has shown that the highest straw yield was obtained in the population cultivar Monolit and the significantly lowest, on average by 0.38 $Mg \cdot ha^{-1}$, was in the semi-dwarf hybrid PX115 Similar study results were obtained by Gugała *et al.* (2019), who showed that the side-line yield of the semi-dwarf cultivar PR44D06 was on average lower by about 4.0% compared to other winter oilseed rape cultivars.

Interactions of the cultivars and foliar feeding types were found with respect to the side-line yield, which shows the individual reaction of cultivars to the applied foliar fertilization. In the population morphotype, the use of the biostimulant Aminoplant did not significantly increase the straw yield compared to the control variants. In the restored hybrids, foliar fertilization with sulphur and boron significantly increased the value of this trait compared to the control variants, while application of the biostimulant Aminoplant in combination with foliar fertilization did not significantly increase the size of the side-line yield.

After the application of foliar feeding with an amino acid the value of the harvest index was the same as in the control variants. Preparations containing sulphur, boron, and amino acids significantly increased the value of the harvest index. The highest value of this index was found after the application of foliar fertilizers containing sulphur and boron in combination with the biostimulant Aminoplant. However, Jankowski *et al.* (2016b) after the application of intensive foliar fertilization showed a decrease in this index value, while Abdulkhaleq *et al.* (2018) found no significant impact of zinc-containing fertilizers on the harvest index. Kaur *et al.* (2019) came to similar conclusions after the application of foliar fertilizers containing sulphur, nitrogen and phosphorus.

The ratio of seed yield to biomass yield (harvest index – HI) was the most favourable for the restored cultivar with the semi-dwarf growth type.

In the present author's study, the impact of foliar feeding on the harvest index depended on genetic factors. In the population cultivar the highest value of the harvest index was recorded after foliar feeding applied in combination with the biostimulant Aminoplant (treatment 4), while the heterosis morphotypes (PT248 and PX115) had the same index value as in the control after the application of the biostimulant Aminoplant.

Climatic conditions prevailing in the years of the study were diverse and significantly affected the thousand seed weight, seed yield, straw yield and harvest index (Table 3). The highest thousand seed weight, seed yield and straw yield was obtained in the 2016–2017 growing season, which was distinguished by a much higher total rainfall from the starting of growth in the spring up to the technical maturity of seeds in comparison to the average for the multi-year period (Table 3, 4). The smallest values of the examined traits were found in the second year of the study, defined as optimal (K = 1.44), in which the largest annual total rainfall was recorded (on average 414.5 mm) and the mean air temperature was 1.1°C higher than that for the multiyear average. In September of this year the mean total rainfall was on average about 50% higher compared to the 1996–2010 mean, while from May to June it was lower than the multi-year totals. According to Jankowski (2007), heavy rainfall in September may adversely affect the yields. However, in the study by Gugała *et al.* (2019) the highest seed yield was recorded in the season that had the highest rainfall in September and that rainfall was more than twice the long-term mean.

Table 3. Thousand seed weight, seed yield, straw yield, harvest index depending on the climatic conditions in the years of the study

Years of study	Cultivars			Mean
	Monolit	PT 248	PX 115	
Thousand seed weight, g				
2016–2017	5.51	5.75	5.85	5.71[a]
2017–2018	5.27	5.53	5.65	5.49[b]
2018–2019	5.37	5.64	5.75	5.59[c]
Mean	**5.38**	**5.64**	**5.75**	–
Seed yield, $Mg \cdot ha^{-1}$				
2016–2017	3.95 [a]	4.12 [d]	4.33 [h]	**4.14[a]**
2017–2018	2.68 [b]	2.89 [e]	3.30 [fi]	**2.95[b]**
2018–2019	3.09 [c]	3.25 [f]	3.35 [gi]	**3.23[c]**
Mean	**3.24**	**3.42**	**3.66**	–
Straw yield, $Mg \cdot ha^{-1}$				
2016–2017	7.14	6.83	6.73	**6.90[a]**
2017–2018	4.51	4.30	4.19	**4.33[b]**
2018–2019	4.85	4.59	4.46	**4.63[c]**
Mean	**5.50**	**5.24**	**4.63**	–
Harvest index				
2016–2017	0.356	0.376	0.392	**0.375[a]**
2017–2018	0.371	0.400	0.440	**0.404[b]**
2018–2019	0.389	0.415	0.429	**0.411[c]**
Mean	**0.372**	**0.397**	**0.420**	–

values marked with the same letter do not differ significantly at $P = 0.05$

The ratio of seed yield to biomass yield (harvest index – HI) was the highest in the driest and warmest year of the study. The mean value of the hydrothermal coefficient was the lowest during that season (K = 0.75).

Based on the present author's study an interaction of years with cultivars was shown, which means that the cultivars responded to changing climatic conditions in different ways (Table 4). In all morphotypes tested the highest seed yield was found in the first year of the study (ranging from 3.95 to 4.33 $Mg \cdot ha^{-1}$) and the lowest in the growing season 2017–2018. In the semi-dwarf hybrid in 2017–2018 and 2018–2019 differences in the values of seed yield were not statistically significant.

Table 4. Characteristics of climatic conditions in 2016–2019 (Zawady Agricultural Experimental Station, Poland)

Years	Months												
	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII-VII
	Precipitation, mm												Total
2016–2017	31.7	13.6	69.8	19.5	22.5	0.4	15.9	25.1	59.7	49.5	57.9	23.6	**389.2**
2017–2018	54.7	80.6	53.0	21.3	15.8	10.1	3.2	15.4	34.5	27.3	31.5	67.1	**414.5**
2018–2019	24.5	27.4	23.3	9.8	9.0	7.9	4.7	15.0	5.9	59.8	35.9	29.7	**252.9**
Multiyear total (1996–2010)	59.9	42.3	24.2	20.2	18.6	19.0	16.0	18.3	33.6	58.3	59.6	57.5	**427.5**
	Air temperature, ^{o}C												Mean
2016–2017	18.0	14.9	7.0	2.4	0.0	-6.6	-1.3	5.5	6.9	13.9	17.8	16.9	**7.9**
2017–2018	18.4	13.9	9.0	4.1	2.7	-0.7	-4.0	-0.3	13.1	17.0	18.3	20.4	**9.3**
2018–2019	20.6	15.9	9.6	7.9	0.3	-3.0	2.2	4.8	9.8	13.3	17.9	18.5	**9.8**
Multiyear total (1996–2010)	18.5	13.5	7.9	4.0	-0.1	-3.2	-2.3	2.4	8.0	13.5	17.0	19.7	**8.2**

	Sielianinov hydrothermal coefficient*								
	VIII	IX	X	III	IV	V	VI	VII	Mean
2016–2017	0.61	0.28	3.02	1.79	3.19	1.52	1.06	0.47	**1.49**
2017–2018	1.00	1.92	2.36	2.97	0.99	0.59	0.61	1.12	**1.44**
2018–2019	0.40	0.71	0.94	1.16	0.20	1.37	0.63	0.56	**0.75**

*coefficient value (Skowera, 2014): extremely dry (ss) $k \leq 0.4$; very dry (bs) 0.4–0.7; dry (s) 0.7–1.0; rather dry (ds) $1.0 < k \leq 1.3$; optimal (o) $1.3 < k \leq 1.6$; rather wet (dw) $1.6 < k \leq 2.0$; wet (w) $2.0 < k \leq 2.5$; very wet (bw) $2.5 < k \leq 3.0$; extremely wet (sw) $k > 3$

CONCLUSIONS

1. Foliar fertilizers used in the experiment affected an increase in seed yield on average ranging from 2.5% to 18.5%.
2. The most significant increase in the thousand seed weight, seed yield, straw yield and harvest index was obtained after applying mixed fertilizers containing sulphur, boron and amino acids.
3. Additional foliar application of the biostimulant Aminoplant on plots with the population and semi-dwarf hybrid cultivars did not significantly increase the seed yield as compared to the control.
4. Of the compared cultivars the semi-dwarf hybrid (PX115) gave the best yields, while the population cultivar (Monolit) gave the lowest.
5. Climatic conditions in the years of the experiment significantly affected the thousand seed weight, the main and secondary yield as well as the relation of seed yield to biomass yield (HI).

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PLONOWANIE RZEPAKU OZIMEGO W ZALEŻNOŚCI OD NAWOŻENIA DOLISTNEGO

Streszczenie

Zbyt mała ilość składników pokarmowych u roślin wpływa na zaburzenie podstawowych procesów fizjologicznych, osłabienie wzrostu i rozwoju roślin, w konsekwencji przyczynia się do zmniejszania plonowania. Celem badań było określenie wpływu nawozów dolistnych zawierających siarkę, bor, aminokwasy na wielkość plonu nasion trzech morfotypów rzepaku ozimego (Monolit, PX115, PT248). Badania przeprowadzono w latach 2016–2019 w Rolniczej Stacji Doświadczalnej Zawady (52^{o}03' N' 22^{o}33' E), należącej do Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. Doświadczenie polowe założono w układzie losowych podbloków (split-plot) w trzech powtórzeniach. Badanymi czynnikami były: I – trzy morfotypy rzepaku ozimego: populacyjny (odmiana Monolit), zrestorowany o tradycyjnym typie wzrostu (odmiana PT248), zrestorowany o półkarłowym typie wzrostu (odmiana PX115); II – rodzaje dokarmiania dolistnego: 1. wariant kontrolny – bez stosowania dokarmiania dolistnego i aminokwasów, 2. biostymulator Aminoplant, 3. nawóz dolistny Siarkomag + nawóz dolistny Bormax, 4. nawóz dolistny Siarkomag + nawóz dolistny Bormax + biostymulator Aminoplant. Zastosowane w doświadczeniu nawozy dolistne wpłynęły na zwiększenie masy tysiąca nasion (średnio od 0.9 do 3.4%), plonu nasion (średnio od 2.5 do 18.5%), plonu ubocznego (średnio od 2.1 do 5.4%) oraz indeksu żniwnego (średnio o 4.4 do 7.5%). Z porównywanych odmian najlepszym plonowaniem wyróżniał się mieszaniec półkarłowy (PX115), zaś najsłabszym odmiana populacyjna (Monolit). Największą masę tysiąca nasion, plon główny i uboczny uzyskano w pierwszym roku badań, wyróżniającym się wyższą sumą opadów podczas wykształcania nasion i dojrzewania łuszczyn w porównaniu z wieloleciem, zaś najmniejszą w sezonie wegetacyjnym o najbardziej wilgotnym okresie jesiennym i suchym okresie kwitnienia i dojrzewania łuszczyn. Najbardziej istotne zwiększenie masy tysiąca nasion oraz plonu nasion uzyskano po zastosowaniu nawozów mieszanych zawierających siarkę, bor oraz aminokwasy. Dodatkowa aplikacja dolistna biostymulatora Aminoplant na poletkach z odmianą populacyjną i mieszańcową półkarłową nie zwiększała istotnie plonu nasion w porównaniu z obiektem kontrolnym. Wykazano istotny wpływ czynnika genetycznego oraz warunków klimatycznych na omawiane cechy.

Słowa kluczowe: aminokwasy, bor, *Brassica napus* L., dokarmianie dolistne, indeks żniwny, masa tysiąca nasion, plon nasion, plon słomy, siarka