Research Article

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The impact of foliar feeding on the yield components of three winter rape morphotypes (*Brassica napus* L.)

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Abstract: The aim of the study was to determine the impact of foliar fertilizers containing amino acids, sulphur, boron on the number of productive branches, the number of pods per plant, the number of seeds in pods and the length of pods of three winter rape (*Brassica napus*) varieties (Monolit, PX115, PT248). The research was carried out in 2016-2017, 2017-2018, 2018-2019 at the Zawady Agricultural Experimental Station (52°03'N and 22°33'E) belonging to the University of Natural Sciences and Humanities in Siedlce, Poland. The field experiment was set up in a split-plot layout in triplicate. The area of one plot for harvest was 21 m². The examined factors were I - morphotype of winter rape: population variety (Monolit), hybrid restored with a semi-dwarf growth type (PX115), hybrid restored with a traditional growth type (PT248). II - types of foliar feeding: 1. treatment without biostimulator and foliar feeding, 2. Bioregulator Aminoplant, 3. Foliar fertilizer Siarkomag with foliar fertilizer Bormax, 4. Foliar fertilizer Siarkomag with foliar fertilizer Bormax and Aminoplant. Variable climatic conditions in the years of the experiment affected the studied components of seed yield of three L. morphotypes. In the year 2016-2017 of research, the plants produced the most productive branches, had the longest pods filled with the largest number of seeds. Foliar nutrition with a biostimulator containing amino acids did not significantly affect the increase of the number of productive branches, pods per plant and pod length compared

to the variant on which no foliar fertilization was applied. Foliar fertilization with S and B in combination with biostimulators was the most effective in increasing the components of seed yield, while the number of productive branches and length of pods under the influence of foliar fertilizers was the same regardless of the application of the biostimulator. The long-stem variety had longer pods that were filled with more seeds than the others.

Keywords: *Brassica napus* L.; Amino acids; Sulphur; Boron; Climatic conditions; Number of productive branches; Number of pods per plant; Number of seeds in pods; Length of pods

1 Introduction

Fertilization is designed to provide nutrients in the right doses and proportions, the right form and time to create optimal conditions for plant growth and development (Barczak and Majcherczak 2008).

Among environmental stresses, the abiotic stress caused by nutrient deficiency is one of the most severe stresses limiting the plant growth and development, as well as crop yield (Bray et al. 2000, Fazili et al. 2010, Ahmadi et al. 2016, Pourjafar and Sharghi, 2016). Noreen et al. (2018) emphasizes that good nutrition of plants with essential nutrients increases the plant's tolerance to abiotic stress.

Foliar nutrition is an effective way to supply macro and microelements, especially in conditions that are not favourable for the proper supply of plants with nutrients through the root system. Foliar fertilization of plants is part of the agricultural technology of many arable crops. Foliar feeding results in faster delivery of deficient nutrients (macro and microelements), high efficiency of small amounts of substances in comparison with soil fertilization, their even distribution, as well as reduction of

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environmental pollution and avoidance of chemical and biological sorption (Tobiasz-Salach *et al.* 2018). Foliar fertilization with quickly available forms of nutrients improves the condition of plants, and thus increases their yields and their quality (Wierzbowska *et al.* 2015).

In agrotechnics of winter rapeseed, foliar nutrition is considered as a basic treatment providing micronutrients to plants, and partially supplementing them with macronutrients. Beneficial effects of foliar nutrition on the growth and development of winter rapeseed plants was demonstrated by Jarecki *et al.* (2019); Kaur *et al.* (2019); Szczepanek and Bech (2019); Wenda-Piesik *et al.* (2017). The positive effect of the Asahi SL biostimulant on rapeseed plants was noted in relation to the plant density (Harasimowicz-Hermann and Borowska 2006, Matysiak *et al.* 2012, Sikorska *et al.* 2018a), plant height (Malarz *et al.* 2008; Sikorska *et al.* 2018a), the first productive branching (Wenda-Piesik *et al.* 2017; Sikorska *et al.* 2018b) and the thickness of the stem at the root (Sikorska *et al.* 2018a). It was also demonstrated that spraying plants with biostimulants has a positive effect on the number of pods per plant (Harasimowicz-Hermann and Borowska 2006; Przybysz *et al.* 2008) and the number of seeds in pods (Harasimowicz-Hermann 2008; Malarz *et al.* 2008), as well as the mass of 1000 seeds (Gugała *et al.* 2019a) and the seed yield (Gugała *et al.* 2019a).

The use of natural plant preparations has a positive effect on the chemical composition of winter rapeseed. Jankowski *et al.* (2016b) with the foliar application of boron obtained an increase in protein concentration in seeds by an average of 8.8 g/kg of d.m. compared to the control variant. Gugała *et al.* (2019b), Kováčik *et al.* (2016) and Spychaj-Fabisiak *et al.* (2011) after applying biostimulants observed a significant increase in raw fat in winter rapeseed seeds. According to Gugała *et al.* (2019b), after the application of natural plant preparations, an increase in crude fibre content in winter rapeseeds was found on average from 0.15 to 0.84 g/kg of d.m.

The research hypothesis was assumed in the work that biostimulators combined with foliar nutrition might have a positive impact on the yield components of three winter rapeseed varieties. The aim of the research was to determine the impact of foliar fertilizers containing amino acids, sulphur, boron on the number of productive branches, the number of pods per plant, the number of seeds in pods and the length of pods of three winter rapeseed varieties (Monolit, PX115, PT248).

2 Materials and methods

2.1 Arrangement of the experiment and research location

The experiment was carried out in 2016-2017, 2017-2018, 2018-2019 at the Zawady (Agricultural Experimental Station - 52°03'N and 22°33'E) belonging to the University of Natural Sciences and Humanities in Siedlce, Poland. The field experiment was set up in a split-plot layout in triplicate. The area of one plot for harvest was 21 m². The examined factors included:

- I. morphotype of winter rapeseed:
 - population variety (Monolit),
 - hybrid restored with a semi-dwarf growth type (PX115),
 - hybrid restored with a traditional growth type (PT248).
- II. types of foliar nutrition:
 - treatment without using foliar feeding and amino acids biostimulator
 - Aminoplant (amino acids, total nitrogen (N) - at least 8.5%): I term used in autumn in the phase of 4-6 leaves (BBCH 14-16), II term, in spring after the beginning of vegetation (BBCH 28-30), III term, in the phase of development of flower buds (budding) – beginning of flowering (BBCH 50-61), at doses of 1.0 dm³·ha⁻¹.
 - foliar fertilizer Siarkomag (5% MgO, total SO₃ - 85%, water-soluble SO₃ - 10%) + Bormax (B - 11%): I – in autumn in the phase of 4-6 leaves (BBCH 14-16), II – in spring after the beginning of vegetation (BBCH 28-30), III – in the phase of development of flower buds (budding) – beginning of flowering (BBCH 50-61), at doses of 2.0 dm³·ha⁻¹ + 0.5 dm³·ha⁻¹
 - foliar fertilizer Siarkomag + Bormax + bioregulator Aminoplant: I term used in autumn in the phase of 4-6 leaves (BBCH 14-16), II term, in spring after the beginning of vegetation (BBCH 28-30), III term, in the phase of development of flower buds (budding) – beginning of flowering (BBCH 50-61), at doses of 2.0 dm³·ha⁻¹ + 0.5 dm³·ha⁻¹ + 1.0 dm³·ha⁻¹.

Monolit is a population variety, characterized by low soil requirements and good frost resistance. PT248 is a restored hybrid with a traditional growth type, while PX115 is a restored morphotype with a semi-dwarf growth type.

In the first year of research, spring wheat was the forecrop for winter rape, in the second and last year of research, it was winter triticale. The experiment was carried out on soil classified according to the World Reference Base for Soil Resources, (2014) in the Haplic Luvisol group, sanded, belonging to the very good rye soil complex, of the IVa class. In the years of research, the pH (pH in 1n KCl) of the soil was slightly acidic and ranged from 5.68 to 5.75. Soil was characterized by low availability of absorbable phosphorus forms and average absorption of potassium and magnesium.

After forecrop harvest, a set of post-harvest procedures was carried out using the ploughing aggregate and open cage roller. Then two weeks after the first procedure, pre-sow ploughing at the depth of 20.0 cm was carried out, using a ring roller at the same time. Before sowing, phosphorus-potassium fertilization (40 kg P·ha⁻¹, 110 kg K·ha⁻¹ and 40 kg N·ha⁻¹ (the first dose). Applied in the form of Lubofos at the dose of 600 kg. Fertilizing doses were supplemented with 55.9 kg·ha⁻¹ of ammonium nitrate, 29.6 kg·ha⁻¹ triple superphosphate and 29 kg·ha⁻¹ potassium salt. The second dose of nitrogen (100 kg·ha⁻¹) in the amount of was applied in spring, before vegetation started (BBCH 28-30) applying ammonium nitrate at the dose of 255.5 kg·ha⁻¹ and ammonium sulphate at the dose of 62.5 kg·ha⁻¹. The third dose of ammonium (60 kg·ha⁻¹) was applied at the inflorescence emergence, by applying ammonium nitrate at the dose of 176.5 kg·ha⁻¹.

Sowing of winter rapeseed was performed with a row spacing of 22.5 cm, assuming a sowing of 60 pcs·m⁻². Sowing was done at the optimal time recommended for this region (in 2016 on August 12, in 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. Rapeseed was harvested in two stages in the first and second decade of July.

Immediately before harvest (BBCH 86-87), on a sample mean of 20 plants from each plot, the components of seed yield were determined:

- number of productive branches (pcs.),
- number of pods per plant (pcs.),
- length of pods (cm),
- number of seeds in pods (pcs.) (taken from the central part of the main shoot and lateral branches).

2.2 Statistical analysis

The results of the study were statistically analysed with the use of the Analysis of Variance (ANOVA). The significance

of variation sources was tested with the “F” Fischer-Snedecor test and the assessment of significance at the significance level of $p=0.05$ between compared means - with Tukey’s range test. Statistical calculations were made on the basis of own algorithm written in Excel in accordance with the above mathematical model:

$$y_{ijl} = m + a_i + g_j + e_{ij}^{(1)} + b_l + ab_{il} + e_{ijl}^{(2)}$$

3 Results and discussion

In the years 2016-2019, different weather conditions prevailed (Figure 1-4, Table 1). In the first year of research, the annual rainfall was 389.2 mm and was lower by an average of 9% compared to the average for many years. Based on the calculated Sielianinov hydrothermal coefficient, the first and second years of the studies were optimal. In the 2017-2018 growing season, the annual rainfall was only 13 mm lower compared to the 1996-2010 average, while the average annual temperature was higher by 1.1°C. The year 2018-2019 of studies was the driest and the warmest. Precipitation in this season was lower by an average of 40.8% than the average for many years, while the average value of the hydrothermal index was the lowest and amounted to 0.75.

This research has shown that climatic conditions significantly affected the components of seed yield of three winter rape morphotypes (Table 2). In the 2016-2017 growing season, the sum of rainfall much higher than the multiannual average in the period from March to April caused the plants to produce the largest number of productive branches, pods, seeds in pods and plants had the largest length of pods. The smallest number of productive branches was obtained in the last year of the study, in which very little rainfall was recorded in April, while the number of pods per plant, length of pods and number of seeds in pods in the second year of the study with a sum of rainfall lower by an average of 53.2% in May.

Interactions of varieties and research years were found in relations to the number of productive branches, which indicates the individual response of varieties to climatic conditions prevailing in individual study years (Table 2). The highest number of productive branches in all varieties was recorded in the first year of research, and the smallest in the 2018-2019 growing season, while in the case of a restored PX115, the value of this parameter was the same in the last two years of research and amounted to 5.5 pieces, on average. The Monolit population variety and PX115 restored hybrid, in the first year of the studies, had

Figure 1: Monthly precipitation sums and average air temperature in given growing seasons RSD Zawady of many years (1996-2010)

Figure 2: Monthly rainfall totals and average air temperature during the growing season 2016-2017 in RSD Zawady of many years of many years (1996-2010)

Figure 3: Monthly rainfall totals and average air temperature during the growing season 2017-2018 in RSD Zawady of many years (1996-2010)

Table 1: Characteristics of weather conditions in the years 2016-2019 (Zawady Meteorological Station. Poland)

Sielianinovs hydrothermic coefficients*									
Years	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

*Index value (Skowera, 2014): extremely dry $k \leq 0.4$, very dry $0.4 < k \leq 0.7$, dry $0.7 < k \leq 1.0$, rather dry $1.0 < k \leq 1.3$, optimal $1.3 < k \leq 1.6$, rather humid $1.6 < k \leq 2.0$, humid $2.0 < k \leq 2.5$, very humid $2.5 < k \leq 3.0$, extremely humid $k > 3.0$

the same number of productive branches, in the second year of research, a similar tendency was observed in the population morphotype and the long-stem hybrid, while in the last growing season in all tested varieties. This research did not show the interaction of years with varieties in relation to the number of pods per plant, length of pods and the number of seeds in pods.

Based on the conducted research, it was found that the number of productive branches depended significantly on the types of foliar fertilization (Table 3). Only after using a biostimulator containing amino acids, the value of this parameter was the same as on the control treatment. Sikorska et al. (2018b), obtained different results, who showed the largest increase in this parameter by an average of 18.3%, under the impact of the Asahi SL bioregulator. Similarly, after the application of the preparation based on amino acids of plant origin and extracts from sea brown algae, Wenda-Piesik et al. (2017), found that the plants produced more productive branches on average from 36 to 72% compared to the variant without using foliar feeding and amino acids biostimulator. In our research, the most productive branches were noted after the application of the Siarkomag with Bormax and Aminoplant (treatment 4). This means that the biostimulator in connection with foliar fertilizers containing S and B stimulated the number of productive branches. Different results were obtained by Jarecki and Bobrecka-Jamro (2008), who did not prove the significant impact of this

Figure 4: Monthly rainfall totals and average air temperature during the growing season 2018-2019 in RSD Zawady of many years (1996-2010)

factor on the value of this parameter. Of the compared varieties, the largest number of productive branches was found in PT248 (on average 6.1 pcs.). This is in line with the results of Sikorska *et al.* (2018b). In contrary, Jarecki and Bobrecka-Jamro (2008) did not find any significant differences in the number of productive branches of the evaluated varieties (Lirajet, Marita, Lisek).

The effect of foliar nutrition on the number of productive branches depended on the genetic factor (Table 3). As a result of using the Aminoplant biostimulator in the studied morphotypes, the same number of productive branches was found. All varieties had the highest value of this parameter on the fourth treatment, where the Aminoplant biostimulator was used with foliar fertilizers containing S and B. In addition, it was shown that the differences between the Monolit and the semi-dwarf hybrid on the control treatment and with the Aminoplant biostimulator (treatment 2) were statistically insignificant. On treatment 3, where foliar nutrition was sulphur and boron was applied, the value of this parameter in the Monolit

and PT248 was the same. A similar tendency was observed on treatment 4 in restored hybrids PT248 and PX115.

Our data showed that the application of the Aminoplant biostimulator (treatment 2) did not affect the significant increase in the number of pods per plant compared to the control treatment, while after the application of foliar nutrition with sulphur and boron, this number increased on average by 16.3 pcs. (treatment 3), while the differences between treatments 2 and 3 were statistically insignificant (Table 3). Different results were obtained by Harasimowicz-Hermann and Borowska (2006) and Sikorska *et al.* (2018b), who proved a significant positive effect of growth biostimulators on the number of pods per plant. In this work, the highest number of pods per plant was recorded after the use of preparations containing S (sulphur), B (boron) and amino acids (treatment 4), while the value of this parameter was the same on treatments 3 and 4. Jarecki *et al.* (2019), as a result of applying the Insol 5 fertilizer only in autumn, did not find a significant effect of the factor on the value of the parameter, but in other variants

Table 2: Yield components depending on varieties and climatic conditions in the years of research

Years	Cultivars			Mean
	Monolit	PT 248	PX 115	
Number of productive branches (pcs.)				
2016-2017	7.1	7.3	7.1	7.2
2017-2018	5.9	5.8	5.5	5.8
2018-2019	5.4	5.5	5.5	5.5
Mean	6.1	6.2	6.0	-
			LSD _{0.05} for:	
			cultivars	0.10
			years	0.10
			interaction: cultivars x years	0.17
Number of pods per plant (pcs.)				
2016-2017	145.0	155.1	150.4	150.2
2017-2018	127.2	130.5	126.9	128.2
2018-2019	135.7	142.0	135.1	137.7
Mean	136.0	142.7	137.4	-
			LSD _{0.05} for:	
			cultivars	n.s.
			years	9.1
			interaction: cultivars x years	n.s.
Length of pods (cm)				
2016-2017	7.7	8.1	7.9	7.9
2017-2018	6.5	6.8	6.4	6.6
2018-2019	6.5	7.5	7.3	7.1
Mean	6.9	7.5	7.2	-
			LSD _{0.05} for:	
			cultivars	0.40
			years	0.40
			interaction: cultivars x years	n.s.
Number of seeds in pods (pcs.)				
2016-2017	26.8	28.2	27.7	27.6
2017-2018	20.7	22.2	21.2	21.4
2018-2019	24.5	25.9	25.4	25.3
Mean	24.0	25.4	24.8	-
			LSD _{0.05} for:	
			cultivars	0.34
			years	0.34
			interaction: cultivars x years	n.s.

n.s. - non significant differences

the foliar nutrition significantly increased the discussed parameters compared to the variant on which this fertilization was not used. Szczepanek and Bech (2019), under the influence of foliar fertilization with potassium, phosphorus, boron and molybdenum (Phostrade®), while Kaur et al. (2019) as a result of foliar application of nitro-

gen, phosphorus and sulphur obtained a greater number of pods per plant compared to the control variant. Czarnik et al. (2015) as a result of the application of the Basfoliar 12-4-6 + S + amino foliar preparation recorded an average of 11% more pods per plant. According to Jarecki and Bobrecka-Jamro (2008), fertilizers used together Basfo-

Table 3. Yield components depending on foliar feeding

TYPES OF FOLIAR FEEDING Monolit		Cultivars			Mean
		PT 248	PX 115		
Number of productive branches (pcs.)					
1.	control variant	5.5	5.8	5.6	5.6
2.	Biostimulator Aminoplant	5.6	5.9	5.6	5.7
3.	Foliar fertilizer Siarkomag + foliar fertilizer Bormax	6.6	6.5	6.3	6.4
4.	Foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulator Aminoplant	6.9	6.7	6.6	6.7
Mean		6.1	6.2	6.0	-
LSD _{0.05} for:					
cultivars					0.10
types of foliar feeding					0.12
interaction: cultivars x types of foliar feeding					0.19
Number of pods per plant (pcs.)					
1.	control variant	127.8	122.8	131.9	127.5
2.	Biostimulator Aminoplant	130.6	141.1	133.2	135.0
3.	Foliar fertilizer Siarkomag + foliar fertilizer Bormax	140.2	150.8	140.4	143.8
4.	Foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulator Aminoplant	145.3	155.9	144.4	148.5
Mean		136.0	142.7	137.4	-
LSD _{0.05} for:					
cultivars					n.s.
types of foliar feeding					10.95
interaction: cultivars x types of foliar feeding					n.s.
Length of pods (cm)					
1.	control variant	6.7	7.1	6.9	6.9
2.	Biostimulator Aminoplant	6.0	7.2	7.0	6.7
3.	Foliar fertilizer Siarkomag + foliar fertilizer Bormax	7.3	7.6	7.4	7.5
4.	Foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulator Aminoplant	7.5	7.9	7.6	7.7
Mean		6.9	7.5	7.2	-
LSD _{0.05} for:					
cultivars					0.40
types of foliar feeding					0.48
interaction: cultivars x types of foliar feeding					n.s
Number of seeds in pods (pcs.)					
1.	control variant	22.4	23.7	22.9	23.0
2.	Biostimulator Aminoplant	23.1	24.0	23.3	23.5
3.	Foliar fertilizer Siarkomag + foliar fertilizer Bormax	24.5	26.4	25.8	25.6
4.	Foliar fertilizer Siarkomag + foliar fertilizer Bormax + biostimulator Aminoplant	26.1	27.6	27.1	26.9
Mean		24.0	25.4	24.8	-
LSD _{0.05} for:					
cultivars					0.34
types of foliar feeding					0.33
interaction: cultivars x types of foliar feeding					0.52

n.s. - non significant differences

liar 36 Extra with Solubor DF and Basfoliar 12-4-6+S with Solubor DF stimulated the number of pods from a plant. A positive impact of the Rolvit B foliar fertilizer on the values of this parameter was also noted by Szewczuk (2003).

This research found that the genetic factor did not significantly affect the number of pods on plants. This is in line with the results of El Habbash and El Salam (2009). Similarly, Czarnik et al. (2015) did not show significant differences between the Arot population variety and the Primus F₁. In turn, Sikorska et al. (2018b) showed the highest value of the discussed parameter in the long-stem variety PT205, significantly smaller in the PR44D06, while the smallest in the Monolit.

This study showed that under the influence of a biostimulator containing amino acids, the length of the pods was the same as on the treatment 1 (Table 3). The largest significant increase in this parameter was noted after the use of foliar fertilization with S, B and amino acids (treatment 4), while the additional use of a biostimulator in combination with foliar feeding did not significantly increase the length of the pods. Similar results were obtained by Kaur et al. (2019). Of the compared morphotypes, restored hybrids with traditional and semi-dwarf growth types were characterized by the largest length of pods, while the differences between the population and semi-dwarf varieties were not statistically significant.

The foliar fertilization used in the experiment significantly increased the number of seeds in pods (Table 3). As a result of using preparations Siarkomag, Bormax and Bioregulator (amino acids), this number increased on average by 3.9 pcs. This is in line with the results of Jankowski et al. (2016a, b), Qin et al. (2017), Szczepanek and Bech (2019) and Kaur et al. (2019). While Jarecki and Bobrecka-Jamro (2008), Czarnik et al. (2015) and Jarecki et al. (2019) did not show a significant impact of foliar nutrition on the value of this parameter.

Of the compared varieties, the largest number of seeds in pods was recorded in a restored hybrid with a traditional type of growth. This is in line with the results of Sikorska et al. (2018b). Different results were obtained by El Habbash and El Salam (2009). Similarly, Czarnik et al. (2015) did not find any significant differences between the population and mixed morphotype.

Interactions of foliar nutrition types and varieties were observed in relations to the number of seeds in pods, which indicates the individual response of the varieties studied to foliar fertilization (Table 3). In the studied morphotypes, the highest value of this parameter was recorded on treatment 4, where foliar nutrition Siarkomag, Bormax and Bioregulator (amino acids) was applied. The number of seeds in pods was the same for the population

variety and semi-dwarf hybrid on variant 1 and 2, while for restored hybrids PT248 and PX115 on treatment 4, after the application of preparations Siarkomag with Bormax and bioregulator Aminoplant.

4 Conclusions

1. Variable climatic conditions in the years of the experiment affected the studied components of seed yield of three winter rape morphotypes. In the first year of research, the plants produced the most productive branches, had the longest pods filled with the largest number of seeds.
2. Foliar nutrition with a biostimulator containing amino acids did not significantly affect the increase of the number of productive branches, pods per plant and pod length compared to the variant on which no foliar fertilization was applied.
3. Foliar fertilization with S and B in combination with biostimulators was the most effective treatment in increasing the components of seed yield, while the number of productive branches and length of pods under the influence of foliar fertilizers was the same regardless of the application of the biostimulator.
4. The long-stem variety had longer pods that were filled with more seeds than the others.

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References

- [1] Ahmadi SAK, Ebadi A, Daneshian J, Siadat SA, Jahanbakhsh S. Effect of drought stress and foliar application of growth regulators on photosynthetic pigments and seed yield of rapeseed (*Brassica napus* L. cv. Hyola 401). Iranian Journal of Crop Sciences. 2016;18(3):Pe196-Pe217 ref.many
- [2] Barczak B, Majcherczak E. Effect of varied fertilization with sulphur on selected spring barley yield structure components. J Cent Eur Agric. 2008;9(4):777-884.
- [3] Bray EA, Bailey SE, Weretilnyk E. Responses to abiotic stresses. In Biochemistry and Molecular Biology of Plants.

- Buchanan W, Gruissem R, Jones (Eds.). Amer. Soc. Plant Physiol. 2000;1158-1176.
- [4] Czarnik M, Jarecki W, Bobrecka-Jamro D, Jarecka A. The effects of sowing density and foliar feeding on yielding of winter oilseed rape cultivars, Rośliny Oleiste - Oilseed Crops. 2015;36(1):60-68. (in Polish)
- [5] El Habbasha EF, El Salam M. Response of two canola varieties (*Brassica napus* L.) to nitrogen fertilizer levels and zinc foliar application. *uc Davis*: Department of Plant Sciences, UC Davis; 2009. Retrieved from <https://escholarship.org/uc/item/68f0h22d>
- [6] Fazili IS, Masoodic M, Ahmadad S, Jamalae A, Khanf JS, Abdina MZ. Interactive effect of sulfur and nitrogen on growth and yield attributes of oilseed crops (*Brassica campestris* L. and *Eruca sativa* Mill.) differing in yield potential. J Plant Nutr. 2010;33(8):1216-1228.
- [7] Gugala M, Sikorska A, Findura P, Kapela K, Malaga-Tobola U, Zarzecka K, et al. Effect of selected plant preparations containing biologically active compounds on winter rape (*Brassica napus* L.). Yielding. Appl. Ecol. Env. Res. 2019a;17(2):2779-2789.
- [8] Gugala M, Sikorska A, Zarzecka K, Findura P, Malaga-Tobola U. Chemical Composition of Winter Rape Seeds Depending on the Biostimulators Used. Agronomy (Basel). 2019b;9(11):716.
- [9] Harasimowicz-Hermann, G., Borowska, M., 2006. Effect of biostimulant Asahi SL in winter rapeseed depending on pluviothermic conditions. Rośliny Oleiste - Oilseed Crops, XXVII(1). 2006;95-106.
- [10] Harasimowicz-Hermann G. Modelling of field structure elements of winter rape by introducing Asahi SL in to cultivation technology. Book of abstracts of Conference: "Biostimulators in modern agriculture" 7-8 February 2008, Warsaw, Poland; 2008. pp. 90.
- [11] Jankowski KJ, Hulanicki PS, Krzebietke S, Żarczyński P, Hulanicki P, Sokółski M. Yield and quality of winter oilseed rape in response to different systems of foliar fertilization. J Elem. 2016a;21(4):1017-1027.
- [12] Jankowski KJ, Sokółski M, Dubis B, Krzebietke S, Żarczyński P, Hulanicki P, et al. Yield and quality of winter oilseed rape (*Brassica napus* L.) seeds in response to foliar application of boron. Agric Food Sci. 2016b;25(3):164-176.
- [13] Jarecki W, Bobrecka-Jamro D. Reaction of winter rape to the extra feeding of its leaves, Annales Universitatis Mariae Curie-Skłodowska LUBLIN – POLONIA, LXIII (2) SECTIO E. 2008;86-96.
- [14] Jarecki W, Buczek J, Bobrecka-Jamro D. The response of winter oilseed rape to diverse foliar fertilization. Plant Soil Environ. 2019;65(3):125-130.
- [15] Kaur M, Kumar S, Kaur A. Effect of foliar application of nitrogen, phosphorus and sulphur on growth and yield of Gobhi Sarson (*Brassica napus* L.) in central Punjab. J Oilseed Brassica. 2019;10(1):47-50.
- [16] Kováčik P, Šimanský V, Wierzbowska J, Renčo M. Impact of foliar application of biostimulator Mg-Titanit on formation of winter oilseed rape phytomass and its titanium content. J Elem. 2016;21(4):1235-1251.
- [17] Malarz W, Kozak M, Kotecki A. The use of Asahi SL biostimulator in spring rape growing. Biostimulators in modern agriculture. Field crops. red. Warszawa: Dąbrowski Z.; 2008. pp. 25-32.
- [18] Noreen S, Fatima Z, Ahmad S, Athar HR, Ashraf M. Foliar Application of Micronutrients in Mitigating Abiotic Stress in Crop Plants. In: Hasanuzzaman M, Fujita M, Oku H, Nahar K, Hawrylak-Nowak B, editors. Plant Nutrients and Abiotic Stress Tolerance. Singapore: Springer; 2018. https://doi.org/10.1007/978-981-10-9044-8_3.
- [19] Pourjafar HZ, Sharghi Y. Effect of foliar application of Nano iron and manganese chelated on yield and yield component of canola (*Brassica napus* L.) under water deficit stress at different plant growth stages Leila, Agric. Sci. Digest. 32016;6(3):172-178.
- [20] Przybysz A, Małeczka-Przybysz M, Słowiński A, Gawrońska H. The effect of Asahi SL on growth, efficiency of photosynthetic apparatus and yield of field grown oilseed rape. In: Dąbrowski ZT, editor. Monographs Series: Biostimulators in Modern Agriculture: Field Crops. Warsaw: Editorial House Wieś Jutra; 2008. pp. 7-17.
- [21] Sikorska A, Gugala M, Zarzecka K. Response of winter rapeseed to biostimulator application and sowing method. Part I. Field architecture elements. Acta Sci Pol Agric. 2018;17(4):205-214.
- [22] Sikorska A, Gugala M, Zarzecka K. Response of winter rapeseed to biostimulator application and sowing method. Part II. Seed yield components. Acta Sci Pol Agric. 2018;17(4):215-223.
- [23] Skowera B. Changes of hydrothermal conditions in the Polish area (1971–2010) [in Polish]. Fragn Agron. 2014;31(2):74-87.
- [24] Szychaj-Fabisiak E, Murawska B, Pacholczyk Ł. Values of quality traits of oilseed rape seeds depending on the fertilisation and plant density. J Elem. 2011;16(10):115-124.
- [25] Szczepanek M, Bech A. Technology of winter oilseed rape with foliar fertilization. Acta Sci Pol Agric. 2019;18(1):39-47.
- [26] Szewczuk C. Effect of application of chosen foliar fertilizers on winter hardiness and seed yields of winter rape. Acta Agrophysica. 2003;85:289-295.
- [27] Tobiasz-Salach R, Krochmal-Marczak B, Bobrecka-Jamro D. Evaluating the influence of foliar fertilization on the yield and chemical composition of buckwheat (*Fagopyrum Esculentum* moench). Fragn Agron. 2018;35(1):106-114.
- [28] Wenda-Piesik A, Kazek M, Ropińska P. Impact of amino acid biostimulation and microelements fertilization in foliar application on productivity of winter oilseed rape. Fragn Agron. 2017;34(3):119-129.
- [29] Wierzbowska J, Cwalina-Ambroziak B, Głosek M, Sienkiewicz S. Effect of biostimulators on yield and selected chemical properties of potato tubers. J Elem. 2015;20(3/2015):757-768.
- [30] World reference base for soil resources. International soil classification system for naming soils and creating legends for soil. FAO, World Soil Resources Reports, 106, Rome, Field experiment; 2014. <http://www.fao.org>
- [31] Qin S, Hu C, Tan Q, Sun X. Effect of molybdenum levels on photosynthetic characteristics, yield and seed quality of two oilseed rape (*Brassica napus* L.) cultivars. Soil Sci Plant Nutr. 2017;63(2):137-144.