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RESPONSE OF WINTER RAPESEED TO BIOSTIMULATOR APPLICATION AND SOWING METHOD PART II. SEED YIELD COMPONENTS

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ABSTRACT

Background. The use of natural growth stimulants is becoming an increasingly common practice in agriculture. Biostimulants favourably affect the plant growth and development and increase the resistance of plants to the adverse effects of various stress factors. The aim of the study was to estimate the effect of types of the applied biostimulators and sowing methods on the number of productive tillers, the number of pods per plant, the length of pods and the number of seeds per pod in three cultivars of winter oilseed rape.
Material and methods. A field experiment was carried out in 2013–2016 at the Agricultural Experimental Station in Zawady (52°03' N; 22°33' E) which belongs to the University of Natural Sciences and Humanities in Siedlce, Poland. The experiment was conducted in a split-split-plot design with three replications. The studied factors included: I – three cultivars of winter oilseed rape: Monolit (population cultivar), PR44D06 (restored hybrid cultivar with a semi-dwarf type of growth), PT205 (restored hybrid cultivar with a traditional type of growth); II – two sowing methods: row spacing of 22.5 cm (row sowing – sowing rate of 60 seeds per 1 m^2), row spacing 45.0 cm (single seed sowing – sowing rate of 40 seeds per 1 m^2); III – three types of applied biostimulants: control variant (without the application of biostimulants), biostimulant Tytanit®, biostimulant Asahi®SL, biostimulant Silvit®.
Results. The present study showed a significant effect of the types of biostimulants used on the seed yield components. Sowing methods did not cause significant changes in the seed yield components, such as: the length of pods, the number of seeds per pod. Differences between the cultivars in the pod length were statistically insignificant. Diversified humidity and thermal conditions prevailing in the years of conducting the experiment significantly affected the seed yield components.
Conclusion. Under the influence of the biostimulant Asahi SL, there was a significant increase in the number of productive tillers, the number of pods per plant, the length of pods, the number of seeds per pod compared to the control variant. In the wider row spacing there was a greater number of productive tillers and pods per plant. The long-stemmed cultivar PT205 compared to the semi-dwarf PR44D06 and the population Monolith formed more productive tillers and pods per plant, while the restored hybrids possessed significantly more seeds per pod compared to the traditional cultivar. The highest values of the examined characteristics were recorded in the growing season 2013-2014, distinguished by the best pluvio-thermal conditions during spring and summer oilseed rape development.

Key words: bioregulators, *Brasscia napus* L., morphotype, number of pods per plant, number of productive tillers, number of seeds per pod, pods length, sowing methods

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INTRODUCTION

In 2012-2015, the area of winter rape cultivation in Poland ranged from 720.3 to 932.4 thousand ha, while in 2016 it was 786 thousand ha, and currently it is 879.1 thousand ha (GUS, 2017). The area, yields and crops of this plant show an upward trend. However, in individual years deviations from this trend are observed due to unfavourable thermal and humidity conditions prevailing during the growing season. According to Van Oosten *et al*. (2017), the use of stimulating substances that improve the condition of plants and provide protection against biotic and abiotic stress becomes an increasingly common practice in agriculture. According to Paradikovic *et al*. (2011), the use of natural or synthetic biostimulant preparations improves the biochemical, morphological and physiological processes occurring in field crops. Natural growth promoters include preparations containing free amino acids, extracts of marine algae and fruits, microorganisms, as well as humic compounds and chitosan (Calvo, 2014). Kolomaznik *et al*. (2012) emphasize that the effectiveness of bioregulators is determined by many factors, including the appropriate selection of biopreparations, their dose, concentration and application methods, as well as plant species and cultivars, and environmental factors.

The study assumes a research hypothesis that the sowing method and the types of biostimulants used may favourably affect the components of the winter rape oilseed seed yield. Due to the few studies on the effect of these factors on the studied characteristics and considering the wide interest of farmers in the study results, research was undertaken to determine the effect of the types of biostimulants used and the sowing methods on the number of productive tillers, the number of pods per plant, the length of pods and the number of seeds per pod in three winter oilseed rape cultivars (Monolit, PR44D06, PT205).

MATERIAL AND METHODS

A field experiment was conducted in 2013-2016 at the Agricultural Experimental Station in Zawady (52°03' N; 22°33' E) which belongs to the University of Natural Sciences and Humanities in Siedlce. The field experiment included the following factors:

factor I – cultivar:
- Monolit (population),
- PR44D06 (restored hybrid with a semi-dwarf type of growth),
- PT205 (restored hybrid with a traditional type of growth);

factor II – sowing methods:
- row spacing of 22.5 cm (row sowing – sowing rate of 60 seeds per 1 m^2),
- row spacing of 45.0 cm (single seed sowing – sowing rate of 40 seeds per 1 m^2);

factor III – types of the applied biostimulants
- the control variant – without the use of biostimulants,
- biostimulant Tytanit®: I date – in autumn at the 4–8 leaf stage (BBCH 14–18), II date – in spring after starting growth (BBCH 21–36), III date – at the flower bud formation (budding) – beginning of flowering (BBCH 50–61), in doses 0.20 $dm^3 \cdot ha^{-1}$ each,
- biostimulant Asahi®SL: I date – in autumn at the 3–5 leaf stage (BBCH 13–15), II date – in spring after starting growth (BBCH 28–30), III date – two weeks after the second treatment, in doses 0.60 $dm^3 \cdot ha^{-1}$ each,
- biostimulant Silvit®: I date – 3 weeks after emergence (BBCH 12–14), II date – in spring after starting growth (BBCH 28–30), III date – two weeks after the second treatment, in doses 0.20 $dm^3 \cdot ha^{-1}$ each.

The methodology of the field study and climatic conditions in the study years are presented in the first part of the work by Sikorska *et al*. (2018).

Directly before the harvest (BBCH 86–87), on a sample of 20 plants from each plot, the seed yield components were determined:
- the number of productive tillers (pcs),
- the number of pods per plant (pcs),
- the length of pods (cm),
- the number of seeds per pod (pcs).

The number of seeds per pod was determined on a sample of 20 pods collected from the central part of the main stem and side tillers of a single plant.

The influence of biostimulants Tytanit®, Asahi®SL and Silvit® on the thousand seed weight and the seed yield of three winter oilseed rape cultivars (Monolith, PR44D06, PT205) is given in the paper by Gugała et al. (2019).

The results of the study were statistically analysed using the analysis of variance. The significance of the sources of variation was tested by Fischer-Snedecor "F" test, and the assessment of significance of differences at the significance level $P < 0.05$ between the compared averages, using Tukey's multiple intervals.

RESULTS AND DISCUSSION

The winter oilseed rape yield is positively correlated with the thousand seed weight, the number of fruit-bearing tillers, the length of pods and the number of seeds per pod, while a negative relationship was observed between the yield and the number of pods per plant. The thousand seed weight depended on the number of fruit-bearing tillers, the number of pods per plant, the length of pods and the number of seeds per pod (Table 1).

Own research showed that the biostimulants used caused a significant increase in the number of productive tillers in comparison with the control variant (Table 2). The largest increase in this characteristic on average by 18.3% was found on the plot where the bioregulator Asahi SL was used. Under the influence of biopreparations Tytanit and Silvit, this number increased by 9.8% and 14.0%, respectively. This is in line with the results of the studies by Harasimowicz-Hermann and Borowska (2006) and Przybysz *et al*. (2008). According to the above authors, plants treated with the bioregulator Asahi SL were characterized by a 46% increase in the number of productive tillers. Similarly, Wenda-Piesik *et al*. (2017), after the application of a preparation based on plant-derived amino acids and marine brown algae extracts, found that plants produced on average from 36 to 72% more productive tillers compared with the control variant.

The studied cultivars showed a differentiated response to the growth biostimulants used (Table 2). In cv. Monolit, significant differences were noted between the control variant and all biostimulants used and within the biostimulants used. In the case of the semi-dwarf hybrid PR44D06, significant differences were found between the control plot and biostimulants, and moreover, significant differences in the number of fruit-bearing tillers were found between Asahi SL and Tytanit as well as between Asahi SL and Silvit, while no significant differences were found between Tytanit and Silvit. A similar tendency was observed for the cultivar PT 205.

Table 1. Values of correlation coefficients between seed yield components

Characteristics	Yield	Thousand seed weight	Number of fruit--bearing tillers	Number of pods per plant	Length of pods	Number of seeds per plant
Yield	1.000					
Thousand seed weight	0.455*	1.000				
Number of fruit--bearing tillers	0.242*	0.393*	1.000			
Number of pods per plant	-0.118	0.489*	0.670*	1.000		
Length of pods	0.554*	0.480*	0.651*	0.369*	1.000	
Number of seeds per pod	0.791*	0.493*	0.582*	0.175*	0.734*	1.000

*correlations significant at $P < 0.05$

Table 2. Number of productive tillers (pcs.)

Cultivars	Years of study			Sowing methods*		Types of biostimulants used				Mean
	2013–2014	2014–2015	2015–2016	single--seed	row	control variant	Tytanit®	Asahi®SL	Silvit®	
Monolit	8.0	7.6	7.3	8.1	7.2	6.7	7.6	8.3	8.1	7.6
PR44D06	8.1	7.8	7.5	8.2	7.4	7.1	7.9	8.3	7.9	7.8
PT205	8.5	8.0	7.8	8.4	7.8	7.5	8.1	8.7	8.2	8.1
Mean	8.2	7.8	7.5	8.2	7.5	7.1	7.8	8.4	8.1	–

$HSD_{0.05}$ for:
years 0.198 cultivars 0.198 types of biostimulants used 0.382 sowing methods 0.400
interactions:
years × cultivars ns cultivars × types of biostimulants used 0.129 sowing methods × cultivars ns

* row spacing 45.0 cm (single-seed sowing – sowing rate 40 seeds per 1 m^2); row spacing 22.5 cm (row sowing – sowing rate 60 seeds per 1 m^2)
ns – non-significant

Sowing methods significantly affected the number of productive tillers (Table 2). More tillers were obtained in the conditions of a wider row spacing at a sowing rate of 40 seeds per 1 m^2. The results of the present study confirm previous reports by Różyło and Pałys (2011) and by Uzun *et al*. (2012). Different conclusions were drawn by Malarz *et al*. (2006), who recorded a larger number of productive tillers in a row spacing of 15.0 cm compared with 30.0 cm, and Kotecki *et al*. (2007) did not show any significant relationships between a row spacing and the value of this characteristic.

The present study showed a significant effect of the genetic factor on the number of productive tillers (Table 2). The heterosis morphotype with the conventional type of growth was distinguished by a significantly higher value of this characteristic compared with the semi-dwarf cultivar PR44D06 and the population cv. Monolit. Similar results were obtained by Wielebski (2006), who received the largest number of fruit-bearing tillers in mixed hybrids Lubusz and Pomorzanin, and Kotecki *et al*. (2005) in the population cultivars Contact and Wotan. In newer studies by Kotecki *et al*. (2007) and Wielebski (2007), there were no significant differences in the discussed characteristic between the population form Lisek and the mixed hybrid Kaszub and restored BOH3103. However, Malarz *et al*. (2006) received a higher value of the discussed characteristic in the population morphotype than in the heterosis one.

Harasimowicz-Hermann and Borowska (2006) and Przybysz *et al*. (2008) proved a significant positive effect of growth biostimulants on the number of pods per plant, which was also confirmed by the present study where under the influence of the bioregulator Asahi SL, the number of pods per plant was higher on average by 11.9% as compared with the control without the use of biostimulants (Table 3). Different research results were obtained by Budzyński *et al*. (2008) and Matysiak *et al*. (2012), who did not note the significant effect of Asahi SL and Kelpak SL on the value of the characteristic discussed.

The present study confirmed that the number of pods per plant depended significantly on the row spacing (Table 3). A larger value of this characteristic was found in a wide row spacing, when sowing 40 seeds per m^2. This is in line with the results obtained by Ozer (2003), Różyło and Pałys (2011) and Waseem *et al*. (2014). Different results were reported by Malarz *et al*. (2006), who found a larger number of pods per plant with a spacing of 15.0 cm than 30.0 cm. Czarnik *et al*. (2015) on the plot where 60 seeds per m^2 were applied noted a lower value of the discussed characteristic on average by 19.1 compared with the variant with a lower sowing rate (40 seeds per m^2). The lack of a significant effect of this factor on the value of the discussed characteristic was reported by Kotecki *et al*. (2007) and Shahin and Valiollah (2009).

According to Malarz *et al*. (2006) and Wielebski (2007), the number of pods produced on the plant was higher in heterosis morphotypes than in the population one. This is consistent with the results of the present study, in which the largest value of this characteristic was found in the long-stemmed cultivar PT205, significantly smaller in the semi-dwarf hybrid PR44D06, and the smallest in the population cultivar Monolit (Table 3). Variations in hybrid cultivars in terms of this characteristic were also presented by Jarecki *et al*. (2013). Kotecki *et al*. (2005) found the largest number of pods per plant in the population cultivar, while Budzyński and Hłasko-Nasalska (2014) did not find statistically significant differences in the number of pods per plant between the studied morphotypes.

Under the influence of biostimulants used in the experiment, there was a significant increase in the pod length, on average from 0.4 to 0.8 cm in comparison with the control variant (Table 4). The highest increase in the value of this characteristic – on average by 10.8%, was found after the use of the biostimulant Asahi SL, while the lowest – on average by 5.4%, under the influence of the bioregulator Tytanit.

Waseem et al. (2014) obtained longer pods at a spacing of 45.0 and 60.0 cm. In the present study, the length of pods did not depend on the sowing methods used (Table 4).

Analysing the effect of biostimulants on the number of seeds per pod, it was found that the most seeds were obtained in pods collected from the variant on which the biostimulant Asahi SL was used, significantly less on the plots sprayed with the biostimulant Silvit and the least after using the bioregulator Tytanit (Table 5). Harasimowicz--Hermann and Borowska (2006) also obtained a definitely positive effect of the biostimulant Asahi SL on the number of seeds per pod in the study conducted with the use of cultivars: Californium, Lisek, Libomir and Kaszub.

Table 3. Number of pods per plant (pcs.)

Cultivars	Years of study			Sowing methods*		Types of biostimulants used				Mean
	2013–2014	2014–2015	2015–2016	single--seed	row	control variant	Tytanit®	Asahi®SL	Silvit®	
Monolit	181.8	160.5	180.4	182.5	165.9	160.1	172.3	185.2	179.2	174.2
PR44D06	192.5	171.2	190.0	191.7	177.4	173.0	182.0	194.0	189.2	184.6
PT205	197.9	176.6	194.5	195.7	183.7	182.2	186.8	197.2	192.5	189.7
Mean	190.8	169.5	188.3	190.0	175.7	171.8	180.4	192.2	187.0	–

$HSD_{0.05}$ for:

years 1.209 cultivars 1.209 types of biostimulants used 1.132 sowing methods 0.279

interactions:

years × cultivars 2.094 cultivars × types of biostimulants used ns sowing methods × cultivars ns

* row spacing 45.0 cm (single-seed sowing – sowing rate 40 seeds per 1 m^2); row spacing 22.5 cm (row sowing – sowing rate 60 seeds per 1 m^2)
ns – non-significant

Table 4. Length of pods (cm)

Cultivars	Years of study			Sowing methods*		Types of biostimulants used				Mean
	2013–2014	2014–2015	2015–2016	single-seed	row	control variant	Tytanit®	Asahi®SL	Silvit®	
Monolit	8.1	7.8	7.4	7.8	7.7	7.3	7.5	8.1	8.0	7.8
PR44D06	8.4	7.9	7.5	8.0	7.8	7.4	8.0	8.3	8.1	7.9
PT205	8.1	7.9	7.4	7.8	7.8	7.4	7.8	8.2	7.8	7.8
Mean	8.2	7.9	7.4	7.9	7.8	7.4	7.8	8.2	8.0	–

$HSD_{0.05}$ for:

years 0.067 cultivars ns types of biostimulants used 0.142 sowing methods ns

interactions:

years × cultivars ns cultivars × types of biostimulants used 0.246 sowing methods × cultivars ns

* row spacing 45.0 cm (single-seed sowing – sowing rate 40 seeds per 1 m^2); row spacing 22.5 cm (row sowing – sowing rate 60 seeds per 1 m^2)
ns – non-significant

Table 5. Number of seeds per pod (pcs.)

Cultivars	Years of study			Sowing methods*		Types of biostimulants used				Mean
	2013–2014	2014–2015	2015–2016	single-seed	row	control variant	Tytanit®	Asahi®SL	Silvit®	
Monolit	24.8	24.3	20.5	23.2	23.2	21.8	22.5	24.4	24.1	23.2
PR44D06	26.4	25.5	21.6	24.5	24.5	23.0	24.2	26.0	24.8	24.5
PT205	26.5	25.8	21.7	24.9	24.4	23.1	24.7	26.1	24.9	24.7
Mean	25.9	25.2	21.3	24.2	24.0	22.6	23.8	25.5	24.6	–

$HSD_{0.05}$ for:

years 0.400 cultivars 0.400 types of biostimulants used 0.490 sowing methods ns

interactions:

years × cultivars ns cultivars × types of biostimulants used ns sowing methods × cultivars ns

* row spacing 45.0 cm (single-seed sowing – sowing rate 40 seeds per 1 m^2); row spacing 22.5 cm (row sowing – sowing rate 60 seeds per 1 m^2)
ns – non-significant

The present study confirmed that the number of seeds per pod was not affected by the row spacing used in the experiment (Table 5). This is in line with the results presented by Malarz *et al*. (2006) and Champiri and Bagheri (2013), who did not find statistically significant differences, while Shahin and Valiollah (2009) showed only a tendency to increase the value of this characteristic. Different results were obtained by Ozer (2003), who stated that with the increase in row spacing, the number of seeds per pod increased. Similar results were also obtained by Waseem *et al*. (2014).

Of the compared cultivars, the largest number of seeds per pod was obtained in the restored cultivars PT205 and PR44DO6, and the smallest in the traditional form Monolit (Table 5). Similarly, Kotecki *et al*. (2005) and Jankowski and Budzyński (2007) found that the hybrid morphotypes Kaszub and Kronos had a larger number of seeds per pod than the population form Contact. Czarnik *et al*. (2015) did not find any significant differences between the population morphotype and the restored hybrid. Similarly, Wielebski (2007) did not show any significant differences between the population cultivar and the restored hybrids, but he obtained significantly more seeds per pod in the traditional morphotype than in the composed hybrids Kaszub and Mazur. Malarz *et al*. (2006) obtained the highest value of the discussed characteristic in the restored hybrid Kronos, while the difference between the population form Lisek and the complex hybrid Kaszub was only 0.1 pcs.

Meteorological conditions prevailing in the growing seasons differentiated the studied seed yield components. The highest values of all discussed characteristics were found in the growing season 2013–2014, warm and humid during the spring development (Tables 2–5). The present study showed that the shortage of precipitation after resuming the growth and higher average air temperatures compared with the long-term mean in the third year of the study caused that the plants produced the least productive tillers and had the shortest pods filled with the least number of seeds. The lowest number of pods per plant was recorded in the second year of the study, in which the spring starting growth stage was extremely wet (K = 4.63), while the flowering stage was very wet (K = 2.91) (Sikorska *et al*., 2018).

CONCLUSIONS

1. The biostimulants used significantly increased the studied seed yield components compared with the control variant. The largest number of productive tillers, pods per plant, pod length and seeds per pod were obtained under the influence of the biostimulant Asahi SL, and significantly the smallest values of these characteristics were obtained in plants treated with Titanit.
2. In conditions of a narrower row spacing at a sowing rate of 60 seeds per 1 m^2, a smaller number of productive tillers and of pods per plant were obtained. This factor did not cause significant changes in the pod length and the number of seeds per pod.
3. The long-stemmed cultivar PT205 semi-breeding formed more productive tillers and pods per plant, compared with the semi-dwarf PR44D06 and population Monolit, and the restored hybrids were characterized by a significantly larger number of seeds per pod compared with the traditional cultivar.
4. The highest values of the studied characteristics were recorded in the growing season 2013-2014, distinguished by the best pluvio-thermal conditions during the spring and summer growth of winter oilseed rape.

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REAKCJA RZEPAKU OZIMEGO NA STOSOWANIE BIOSTYMULATORÓW ORAZ SPOSÓB SIEWU. CZĘŚĆ II. KOMPONENTY SKŁADOWE PLONU NASION

Streszczenie

Stosowanie naturalnych stymulatorów wzrostu staje się coraz powszechniejszą praktyką w rolnictwie. Biostymulatory wpływają korzystnie na wzrost i rozwój roślin oraz zwiększają odporność roślin na niekorzystne oddziaływanie różnych czynników stresowych. Celem przeprowadzonych badań było określenie wpływu rodzajów stosowanych biostymulatorów oraz sposobów siewu na liczbę rozgałęzień produktywnych, liczbę łuszczyn na roślinie, długość łuszczyn oraz liczbę nasion w łuszczynie w trzech odmianach rzepaku ozimego. Doświadczenie polowe przeprowadzono w latach 2013–2016 w Rolniczej Stacji Doświadczalnej – Zawady (52°03' N; 22°33' E), należącej do Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. Eksperyment przeprowadzono w układzie split-split-plot w trzech powtórzeniach. Badanymi czynnikami były: I – trzy odmiany rzepaku ozimego: Monolit (populacyjna), PR44D06 (mieszańcowa zrestorowana o półkarłowym typie wzrostu), PT205 (mieszańcowa zrestorowana o tradycyjnym typie wzrostu), II – dwa sposoby siewu: rozstawa 22,5 cm (siew rzędowy – gęstość siewu 60 nasion na 1 m^2), rozstawa 45,0 cm (siew punktowy – gęstość siewu 40 nasion na 1 m^2), III – trzy rodzaje stosowanych biostymulatorów: wariant kontrolny (bez stosowania biostymulatorów), biostymulator Tytanit®, biostymulator Asahi®SL, biostymulator Silvit®. Badania własne wykazały istotny wpływ rodzajów stosowanych biostymulatorów na komponenty składowe plonu nasion. Sposoby siewu nie powodowały istotnych zmian w komponentach składowych plonu nasion, takich jak: długość łuszczyn, liczba nasion w łuszczynie. Różnice między odmianami w długości łuszczyn były statystycznie nieistotne. Zróżnicowane warunki wilgotnościowo-termiczne panujące w latach prowadzenia doświadczenia wpływały istotnie na komponenty składowe plonu nasion. Pod wpływem biostymulatora Asahi SL zanotowano istotne zwiększenie liczby rozgałęzień produktywnych, liczby łuszczyn na roślinie, długości łuszczyn, liczby nasion w łuszczynie w porównaniu do wariantu kontrolnego. W szerszej rozstawie międzyrzędzi zanotowano większą liczbę rozgałęzień produktywnych i łuszczyn na roślinie. Odmiana długołodygowa PT205 w porównaniu do półkarłowej PR44D06 i populacyjnej Monolit tworzyła więcej rozgałęzień produktywnych i łuszczyn na roślinie, mieszańce zrestorowane miały istotnie więcej nasion w łuszczynie w stosunku do odmiany tradycyjnej. Największe wartości badanych cech odnotowano w sezonie wegetacyjnym 2013–2014 wyróżniającym się najlepszymi warunkami pluwio-termalnymi podczas wiosenno-letniego rozwoju rzepaku.

Słowa kluczowe: bioregulatory, *Brassica napus* L., długość łuszczyn, morfotyp, liczba łuszczyn na roślinie, liczba nasion w łuszczynie, liczba rozgałęzień produktywnych, sposoby siewu