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

Anna Sikorska1, Marek Gugała2, Krystyna Zarzecka2

1Department of Agriculture, The State Higher School of Vocational Education in Ciechanów, Narutowicza 9, 06-400 Ciechanów, Poland
2Department of Agrotechnology, Faculty of Natural Sciences, Siedlce University of Natural Sciences and Humanities, Prusa St. 14, 08-110 Siedlce, Poland

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 m²), row spacing 45.0 cm (single seed sowing – sowing rate of 40 seeds per 1 m²); 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, Brassica napus L., morphotype, number of pods per plant, number of productive tillers, number of seeds per pod, pods length, sowing methods
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 m²),
  - row spacing of 45.0 cm (single seed sowing – sowing rate of 40 seeds per 1 m²);

- **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 dm³·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 dm³·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 dm³·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 (Monolit, 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

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Yield</th>
<th>Thousand seed weight</th>
<th>Number of fruit-bearing tillers</th>
<th>Number of pods per plant</th>
<th>Length of pods</th>
<th>Number of seeds per pod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thousand seed weight</td>
<td>0.455*</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of fruit-bearing tillers</td>
<td>0.242*</td>
<td>0.393*</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of pods per plant</td>
<td>-0.118</td>
<td>0.489*</td>
<td>0.670*</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of pods</td>
<td>0.554*</td>
<td>0.480*</td>
<td>0.651*</td>
<td>0.369*</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Number of seeds per pod</td>
<td>0.791*</td>
<td>0.493*</td>
<td>0.582*</td>
<td>0.175*</td>
<td>0.734*</td>
<td>1.000</td>
</tr>
</tbody>
</table>

*correlations significant at $P < 0.05$
Table 2. Number of productive tillers (pcs.)

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Years of study</th>
<th>Sowing methods*</th>
<th>Types of biostimulants used</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monolit</td>
<td>8.0</td>
<td>7.6</td>
<td>7.3</td>
<td>8.1</td>
</tr>
<tr>
<td>PR44D06</td>
<td>8.1</td>
<td>7.8</td>
<td>7.5</td>
<td>8.2</td>
</tr>
<tr>
<td>PT205</td>
<td>8.5</td>
<td>8.0</td>
<td>7.8</td>
<td>8.4</td>
</tr>
<tr>
<td>Mean</td>
<td>8.2</td>
<td>7.8</td>
<td>7.5</td>
<td>8.2</td>
</tr>
</tbody>
</table>

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$^2$)

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 Pomorزان, 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 m²). 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.)

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Years of study</th>
<th>Sowing methods*</th>
<th>Types of biostimulants used</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monolit</td>
<td>181.8</td>
<td>160.5</td>
<td>180.4</td>
<td></td>
</tr>
<tr>
<td>PR44D06</td>
<td>192.5</td>
<td>171.2</td>
<td>190.0</td>
<td></td>
</tr>
<tr>
<td>PT205</td>
<td>197.9</td>
<td>176.6</td>
<td>194.5</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>190.8</td>
<td>169.5</td>
<td>188.3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HSD₀.₀₅ for:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>years</td>
<td>1.209</td>
</tr>
<tr>
<td>cultivars</td>
<td>1.209</td>
</tr>
<tr>
<td>types of biostimulants used</td>
<td>1.132</td>
</tr>
<tr>
<td>sowing methods</td>
<td>0.279</td>
</tr>
</tbody>
</table>

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 m²); row spacing 22.5 cm (row sowing – sowing rate 60 seeds per 1 m²)

ns – non-significant
Table 4. Length of pods (cm)

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Years of study</th>
<th>Sowing methods*</th>
<th>Types of biostimulants used</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monolit</td>
<td>8.1</td>
<td>7.8</td>
<td>7.4</td>
<td>7.8</td>
</tr>
<tr>
<td>PR44D06</td>
<td>8.4</td>
<td>7.9</td>
<td>7.5</td>
<td>8.0</td>
</tr>
<tr>
<td>PT205</td>
<td>8.1</td>
<td>7.9</td>
<td>7.4</td>
<td>7.8</td>
</tr>
<tr>
<td>Mean</td>
<td>8.2</td>
<td>7.9</td>
<td>7.4</td>
<td>7.8</td>
</tr>
</tbody>
</table>

HSD₀.₀₅ 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 m²); row spacing 22.5 cm (row sowing – sowing rate 60 seeds per 1 m²)
ns – non-significant

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

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Years of study</th>
<th>Sowing methods*</th>
<th>Types of biostimulants used</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monolit</td>
<td>24.8</td>
<td>24.3</td>
<td>20.5</td>
<td>23.2</td>
</tr>
<tr>
<td>PR44D06</td>
<td>26.4</td>
<td>25.5</td>
<td>21.6</td>
<td>24.5</td>
</tr>
<tr>
<td>PT205</td>
<td>26.5</td>
<td>25.8</td>
<td>21.7</td>
<td>24.9</td>
</tr>
<tr>
<td>Mean</td>
<td>25.9</td>
<td>25.2</td>
<td>21.3</td>
<td>24.2</td>
</tr>
</tbody>
</table>

HSD₀.₀₅ 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 m²); row spacing 22.5 cm (row sowing – sowing rate 60 seeds per 1 m²)
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 Valiolah (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 PR44D06, 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 m², 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.

REFERENCES


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


ACKNOWLEDGEMENTS

The results of the research carried out under the research theme No. 363/S/13 were financed from the science grant granted by the Ministry of Science and Higher Education.
REAKCJA RZEPAKU OZIMEGO NA STOSOWANIE BIOSTYMULATORÓW ORAZ SPOSÓB SIEWU.
CZĘŚĆ II. KOMPONENTY SKŁADOWE PLONU NASION

Streszczenie

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