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TECHNOLOGY OF WINTER OILSEED RAPE WITH FOLIAR FERTILIZATION

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ABSTRACT

Background. Effective fertilizer management strategies are a prerequisite to ensure optimum seed yields and seed quality of oilseed rape. The study aimed to evaluate the effect of the autumn or autumn and spring foliar application of potassium, phosphorus, boron and molybdenum (Phostrade® BMo) on biometric features, overwintering and the quantity and quality of winter oilseed rape yield.
Material and methods. The subject of the study was winter oilseed rape, cv. 'Chagall', cultivated in the successive years 2013-2015, after winter wheat. This study was based on a single-factor field experiment conducted in the Kuyavian-Pomeranian region, Poland, 53°13′ N; 17°51′ E, on Alfisol, in a randomized block design, with four replications. The effect of the different time and a dose of foliar fertilizer Phostrade® BMo (P_2O_5 15% w/w, K_2O 14% w/w, B 0.9% w/w; Mo 0.1% w/w) application was evaluated as follows: 5 $dm^3 \cdot ha^{-1}$ applied in autumn at 5 leaves stage (BBCH 15) or 3 $dm^3 \cdot ha^{-1}$ in autumn (BBCH 15) and 3 $dm^3 \cdot ha^{-1}$ in spring at beginning of stem elongation stage (BBCH 30) and the control.
Results. This study has shown that the application of this fertilizer in autumn, at a dose 5 $dm^3 \cdot ha^{-1}$ or 3 $dm^3 \cdot ha^{-1}$ had a positive effect on the roots dry weight and the roots length of oilseed rape before winter. The influence of the fertilization on the shoots dry weight, the number of pods per plant and the number of seeds per pod as well as the yield of oilseed rape was higher in the year characterized by precipitation deficiency during the spring growth and the generative development. Two-time application of fertilizer, as well as single application in autumn, had a positive effect on the number of seeds per pod and the seed yield as well as the chlorophyll index and the shoots dry weight at the end of flowering.
Conclusion. Sequential application of Phostrade® BMo at doses 3 $dm^3 \cdot ha^{-1}$ in autumn and 3 $dm^3 \cdot ha^{-1}$ in spring, as well as single application at a dose 5 $dm^3 \cdot ha^{-1}$ in autumn, increased the seed yield of open-pollinated variety 'Chagall' of oilseed rape. Further studies are necessary to determine the optimal method of application of this foliar fertilizer in the cultivation of hybrid cultivars of winter oilseed rape.

Key words: biometric features, chlorophyll index, seed yield, oil content

INTRODUCTION

Oilseed rape (*Brassica napus* L.), one of the three major oil crops in the world, provides edible oil and raw materials for bio-energy and is an important source of protein in feed. FAOSTAT statistic data indicate an increase in the economic importance of oilseed rape in the world (FAOSTAT, 2019). In the years 2007–2017, global production of oilseed rape increased by 50.7%, which was associated with an increase in the area of cultivation (by 17.8%), but mainly with an increase in yield (from 1.72 in 2007 to 2.19 $t \cdot ha^{-1}$ in 2017, on average by 27.3%). In the analysed period in Poland, the increase in production

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was lower and amounted to 26.6%, the area increased by 14.7% and the yield by 10.5% (from 2.67 to 2.95 $Mg \cdot ha^{-1}$).

Due to the significant production of dry matter (15.9 $Mg \cdot ha^{-1}$ of the aboveground part and 1.7 $Mg \cdot ha^{-1}$ of roots in the maturing phase) (Szczepanek *et al*., 2017) winter oilseed rape has very high nutritional requirements. The macronutrient uptake of winter oilseed rape in terms of 1 $Mg \cdot ha^{-1}$ of seed and straw yield reaches 50–73 kg N, 9–20 kg P, 33–89 kg K, 4–11 kg Mg and 14-20 kg S (Grzebisz, 2011). Such quantities of nutrients can be supplied effectively only through soil fertilization. Foliar fertilization, as a method of supplying macronutrients, can only be used to reverse the effects of nutritional deficiencies, but it can be the main fertilization technique to supply plants with the micronutrients (Jankowski *et al*., 2016b; Siwik-Ziomek and Szczepanek, 2018). In medium-rich soils with a balanced fertilization regime, foliar application of macronutrients increased seed yield of oilseed rape by 0.09 to 0.22 $Mg \cdot ha^{-1}$ (White *et al*., 2015). When the yield potential is low, a foliar supply of macronutrients could lead to a greater increase in seed yield at 0.46 to 0.54 $Mg \cdot ha^{-1}$ (Kwiatkowski, 2012).

Effective fertilizer management strategies are a prerequisite to ensure optimum seed yields and seed quality. Moreover, such fertilizer management strategies must be economically viable and must ensure minimized negative impacts on the environment. The aim of this study was to evaluate the effect of the time and a rate of the foliar fertilizer Phostrade® BMo on biometric features in autumn, and in spring, as well as on the state of nutrition, as well as the quantity and quality of winter oilseed rape yield.

MATERIAL AND METHODS

Field experiments with winter oilseed rape cv. ‘Chagall’ were carried out in 2013/2014 and 2014/2015. These experiments were conducted in Alfisol (Soil Survey Staff, 2010), where the topsoil was characterized by a low content of available phosphorus and high of potassium, both determined with the Egner-Riehm method. The soil had slightly acidic reaction (pH in 1M KCl 5.78). The content of total nitrogen 0.637 $g \cdot kg^{-1}$ in the soil was relatively low. The winter oilseed rape was sown at 03.09.2013 and 28.08.2014, at a density of 70 $seeds \cdot m^{-2}$.

Pre-sowing mineral fertilization was applied to soil, at rates: 30 $kg \cdot ha^{-1}$ P, 80 $kg \cdot ha^{-1}$ K, 34 $kg \cdot ha^{-1}$ N. Nitrogen was supplied also in a spring, at the beginning of the growing period (90 $kg \cdot ha^{-1}$), and the other part, 70 $kg \cdot ha^{-1}$, after 3 weeks. During the growing season, pesticides were applied to control insects and diseases. The water-soluble foliar fertilizer Phostrade® BMo, which contains P_2O_5 195 $g \cdot dm^{-3}$ (15% w/w), K_2O 182 $g \cdot dm^{-3}$ (14% w/w), B 11.7 $g \cdot dm^{-3}$ (0.9 % w/w), Mo 1.3 $g \cdot dm^{-3}$ (0.1% w/w), was applied once in autumn (in the first 5 days of October) in a dose of 5 $dm^3 \cdot ha^{-1}$, at the 5 leaves stage (BBCH 15) or two times: in autumn in a dose of 3 $dm^3 \cdot ha^{-1}$ at BBCH 15 and in spring (the end of March), in a dose of 3 $dm^3 \cdot ha^{-1}$ at the beginning of stem elongation (BBCH 30). These treatments were compared with the control – without application. Single factor field experiment was carried out with four replication, on plots with an area of 12 m^2 (3 m width and 4 m length). For Phostrade® BMo application the manual sprayer was used. This foliar fertilizer was dissolved in 250 dm^3 per ha of water.

The root crown diameter, number of leaves and apical bud height were measured prior to the end of autumn growth, on successive plants in a row with the length corresponding to an area of 1 m^2. At the same time the roots and shoots dry weight as well as the roots length were assesses on the base of ten plants from each plot. The overwintering was assessed based on the difference in plant density before winter and in spring, at the same place on each plot, on the row length corresponding to 1 m^2. At the end of flowering, the roots and shoots dry weight were assessed on the base of 10 plants from each plot. At ripening, the number of pods per plant and seed per pod were assessed on the base of 10 plants per each plot. The yield (from each plot) was weighed after threshing, its moisture was determined (with the drying method), and then it was calculated at 8% water content. Thousand seed weight was determined, based on 200 seeds from each plot. The leaf greenness index (SPAD) was evaluated using the Chlorophyll Meter SPAD–502. It measures the difference in light absorption with the wavelength of 650 nm, (the maximal light absorption by chlorophyll a and b), and 940 nm (light kept by the leaf tissues). The quotient of those differences is displayed as SPAD (*Soil-Plant Analyses Development*) units and is called the leaf greenness index. Measurements were made prior to the end of autumn growth, and in the middle of May (BBCH 67), on 30 fully formed youngest leaves on each plot. The obtained data were subjected to the statistical analysis. The analysis of variance of single experiments in the years and the synthesis from the years in the mixed model were made using the statistical program Analysis of variance for orthogonal experiments by the UTP University of Science and Technology in Bydgoszcz. Significance of differences for the results were assessed with Tukey's test, assuming the significance level $P < 0.05$.

RESULTS AND DISCUSSION

The weather conditions from sowing to entering the winter dormant period were more favourable for the development of winter oilseed rape in 2014, compared with 2013, mainly due to a higher temperature in September and October (Table 1). In 2014, biometric features of oilseed rape rosette, decisive for wintering, including the number of leaves, the diameter of the root crown, roots and shoots dry weight as well as roots length and chlorophyll index reached higher values compared with 2013 (Table 2). Until the end of autumn growth, oilseed rape developed 7–8 or 8–9 leaves, in 2013 and 2014, respectively. Foliar application of Phostrade® BMo did not affect the number of leaves of the tested oilseed rape variety before winter (Table 2). The root neck diameter, especially in 2013, was slightly higher after the application of foliar fertilization, however, differences in relation to the control were not statistically significant. In 2013, the apical bud was located closer to the soil surface than in 2014. In 2013, the non-fertilized oilseed rape (control) had the bud with a higher location compared with the oilseed rape fertilized with Phostrade® BMo in a dose of 3 dm^3 as well as 5 $dm^3 \cdot ha^{-1}$.

Table 1. Temperature and precipitation from sowing to harvest of winter oilseed rape

Month	Air temperature, °C			Precipitation, mm		
	2013/2014	2014/2015	1996–2014	2013/2014	2014/2015	1996–2014
August	18.1	17.2	17.8	56.6	57.3	66.5
September	10.7	14.4	13.0	64.1	25.9	44.4
October	8.2	9.6	7.9	18.6	18.0	34.5
November	4.9	4.3	3.3	28.5	24.5	33.4
December	1.8	0.5	–0.7	19.1	69.3	35.7
January	–3.2	1.1	–2.3	23.5	33.2	29.1
February	2.0	0.1	–1.1	18.0	8.9	25.5
March	5.6	4.1	2.1	49.7	35.7	32.5
April	9.9	7.5	8.1	40.7	15.6	28.7
May	13.3	12.4	13.2	65.7	21.6	61.1
June	16.0	15.7	16.3	44.9	33.0	53.1
July	21.5	18.5	18.7	55.4	50.4	87.1
Mean/Total	9.07	8.78	8.03	484.8	393.4	531.6

Table 2. Biometric features of winter oilseed rape rosette before winter

Year	Time and dose of Phostrade® BMo				HSD
	Control	5 dm^3·ha^{-1} in autumn	3 dm^3·ha^{-1} in autumn + 3 dm^3·ha^{-1} in spring	Mean	
Number of leaves, pcs					
2013	7.53	7.80	7.74	7.69	ns
2014	8.68	8.98	8.90	8.85	ns
Mean	8.10	8.39	8.32	8.27	ns
Diameter of the root crown, mm					
2013	4.41	4.83	4.80	4.68	ns
2014	7.07	7.28	7.08	7.14	ns
Mean	5.74	6.05	5.94	5.91	ns
Apical bud height, cm					
2013	1.03	0.87	0.85	0.92	0.154
2014	1.43	1.30	1.41	1.38	ns
Mean	1.23	1.08	1.13	1.15	ns
Roots dry weight, g					
2013	0.180	0.216	0.225	0.207	0.043
2014	0.793	0.821	0.821	0.812	ns
Mean	0.486	0.519	0.523	0.509	0.030
Shoots dry weight, g					ns
2013	1.27	1.63	1.51	1.47	0.247
2014	3.95	4.08	4.01	4.01	ns
Mean	2.61	2.85	2.76	2.74	ns
Roots length, cm					
2013	16.4	17.0	17.4	16.9	ns
2014	17.6	18.3	18.4	18.1	ns
Mean	17.0	17.6	17.9	17.5	0.595
Chlorophyll index, SPAD					
2013	473	473	479	475	ns
2014	646	657	646	649	ns
Mean	559	565	562	562	ns

ns – non significant; HSD – honestly significant difference

The beneficial effect of the autumn application of fertilizer Phostrade® BMo (both in a dose of 3 $dm^3 \cdot ha^{-1}$ and 5 $dm^3 \cdot ha^{-1}$) on the dry weight of roots in 2013 and, on average, from two years of the study was shown. The dry weight of the aboveground part was higher than in the control only after application of a dose of 5 $dm^3 \cdot ha^{-1}$ in 2013. On average, from two years of the study, the roots were longer after the foliar fertilizer application in comparison with the control. A study by Qin *et al*. (2017) showed a rising trend in the dry weight of oilseed rape with the increase of Mo level at seedling and stem elongation stages, but no significant difference was observed at the harvest stage, suggesting that oilseed rape is more sensitive to Mo deficiency at seedling and stem elongation stages.

Overwintering of winter oilseed rape depends on the state of rosette development before winter, e.g. the diameter of the root crown and the amount of assimilates stored in it (Velicka *et al*., 2016). In the present study, overwintering of oilseed rape was very good in 2014 and worse in 2015. Higher losses in plant density after winter in 2015 may have resulted from high-placed apical buds, exposed to freezing at low temperatures (monthly average of 0.1°C) and lack of snow cover (total precipitation 8.9 mm) in February 2015 (Table 1). No significant effect of autumn foliar fertilization on overwintering of winter oilseed rape was shown (Table 2).

In 2014 and on average in the long-term period, after the autumn application of the foliar fertilizer Phostrade® BMo in a dose of 5 $dm^3 \cdot ha^{-1}$, the dry weight of roots at the end of flowering (BBCH 67) was higher than in the control (Table 3). The most beneficial effect on the dry weight of the aboveground part in 2015 as well as on average from two years of the study had the two-time application of Phostrade® BMo (in autumn and in spring). The one-time application in autumn had a significantly smaller but also beneficial effect on dry weight of shoots compared with the control. The growth of oilseed rape is most strongly affected by supply in macronutrients, including potassium (Szczepaniak, 2015). Cheema *et al*. (2012) report that increasing rates of K enhanced leaf area index and crop growth.

In our study the chlorophyll index (SPAD value) in autumn and in spring was assessed (Table 2). According to Koeslin-Findeklee *et al*., 2015 this is a good non-destructive method of evaluation the plant nutritional status. In the present study, no significant effect of autumn foliar fertilization on the chlorophyll index before winter was demonstrated. The chlorophyll index measured in the middle of May (BBCH 67) was in 2014 and 2015, as well as on average from two years of the study, significantly greater in the fertilized oilseed rape compared with the control, where the dose and date of the application did not have a significant impact on this plant nutritional index (Table 3). Fanaei *et al*. (2019) indicate an increase in the SPAD value under the influence of potassium fertilization, as well as the relationship between the seed yield and SPAD values.

The amount of root dry weight, the weight of shoots after winter (Table 3), as well as the number of pods, the number of seeds per pod and the winter oilseed yield (Table 4) were from 28% to 70% lower in 2015 compared with 2014. The reason for reduction in the growth and yield of oilseed rape in 2015 was drought. In the period from February to June 2015, the rainfall was only 115 mm, while in 2014 almost twice as much (219 mm) (Table 1). A strong deficit of water occurred in April and May 2015, during the period of intensive shoot elongation and flowering of oilseed rape. Previous studies have shown that the lowest yield of oilseed rape was obtained in the year characterized by limited rainfalls in May and June, i.e. at the stage of flowering and pod formation (Szczepanek *et al*., 2016). In the present study, the foliar application of Phostrade® BMo had a significant, beneficial effect on yield structure components, such as the number of pods per plant and the number of seeds per pod, as well as the seed yield in the year in which drought stress occurred (2015). In that year, the number of pods per plant was the highest after the two-time fertilizer application, significantly lower after one-time application in autumn, and the lowest in the control. On average from the two years of the study, only two-time application had a significant, beneficial effect on the number of pods per plant. The number of seeds per pod in 2015 and on average from two years of the study was significantly higher in plants fertilized with Phostrade® BMo, regardless of the dose and time of its application. Similarly, other studies has noted the beneficial effect of fertilization with Mo on the number of pods per plant (Qin *et al.*, 2017) and of foliar application of B on seed production in pods (Jankowski *et al.*, 2016a).

Table 3. Biometric features of winter oilseed rape after winter

Year	Time and dose of Phostrade® BMo				HSD
	Control	5 $dm^3 \cdot ha^{-1}$ in autumn	3 $dm^3 \cdot ha^{-1}$ in autumn + 3 $dm^3 \cdot ha^{-1}$ in spring	Mean	
Overwintering, %					
2014	99.0	99.4	100	99.5	ns
2015	93.9	94.9	91.9	93.6	ns
Mean	96.4	97.2	96.0	96.5	ns
Roots dry weight, g					
2014	31.3	34.5	33.5	33.1	2.55
2015	19.9	21.9	20.6	20.8	ns
Mean	25.6	28.2	27.0	26.9	1.49
Shoots dry weight, g					
2014	317	332	344	331	ns
2015	170	188	202	187	7.9
Mean	243	260	273	259	10.6
Chlorophyll index, SPAD					
2014	700	735	754	730	26.9
2015	629	665	665	653	23.5
Mean	664	700	709	691	35.0

ns – non significant; HSD – honestly significant difference

The literature data indicate that foliar fertilization with micronutrients increases seed yield by 10-16% (Grzebisz *et al.*, 2010) to even 46–67% (Yang *et al.*, 2009). In the present study, the application of Phostrade® BMo resulted in a significant increase in the seed yield of the tested winter oilseed rape cultivar in the dry year 2015 and on average from two years of the study. Similarly, Jankowski *et al.* (2016a) report that boron fertilization was more effective in increasing seed yield during dry spells in spring. In the present study in 2015, the highest seed yield was obtained after two-time applications of the foliar fertilizer. Significantly lower yields were obtained after one-time application in autumn. On average from two years of the study, the impact of one-time and two-time applications on increasing the seed yield in relation to the control was similar. An increase in rapeseed yield with an increase in the intensity of foliar fertilization (from 4 to 6 applications) is also indicated by a study by Jankowski *et al.* (2016b). Potassium is of particular importance for yielding of winter oilseed rape. The application of a foliar potassium fertilizer can bring a significant increase in seed yield (Szczepanek *et al*., 2016). The response of seed yield depends on the content of K in vegetative parts of oilseed rape during the seed-filling period (Szczepaniak, 2015). Even at the average K content in soil, plants may be insufficiently nourished with this element of exhaustion of resources of this element from the rhizosphere (Shi *et al*., 2014), which can prove the usefulness of its foliar application. Foliar fertilization is particularly important in the case of boron. In a study by Ma *et al*. (2015) there was no change in yield from soil-applied B, the foliar B application at early flowering increased yields up to 10%. In the present study, an increase in the seed yield under the influence of foliar fertilization resulted from an increase in both the number of pods per plant and the number of seeds per pod (Table 4).

Table 4. Yield components and seed yield of winter oilseed rape

Year	Time and dose of Phostrade® BMo				HSD
	Control	5 $dm^3 \cdot ha^{-1}$ in autumn	3 $dm^3 \cdot ha^{-1}$ in autumn + 3 $dm^3 \cdot ha^{-1}$ in spring	Mean	
Number of plants per m^2					
2014	42.3	40.0	42.8	41.7	ns
2015	54.8	54.0	56.5	55.1	ns
Mean	48.5	47.0	49.6	48.4	ns
Number of pods per plant					
2014	381	389	393	388	ns
2015	107	115	129	117	7.5
Mean	244	252	261	252	10.5
Number of seeds per pod					
2014	23.7	24.8	24.6	24.3	ns
2015	16.2	18.3	18.3	17.6	2.08
Mean	19.9	21.5	21.4	21.0	1.45
Thousand seed weight, g					
2014	5.08	5.25	5.20	5.18	ns
2015	5.90	5.76	5.72	5.79	ns
Mean	5.49	5.50	5.46	5.48	ns
Yield, $Mg \cdot ha^{-1}$					
2014	3.86	4.11	4.12	4.03	ns
2015	2.10	2.34	2.58	2.34	0.239
Mean	2.98	3.22	3.35	3.18	0.172

ns – non significant; HSD – honestly significant difference

The literature data indicate that foliar fertilizers improve seed yield by increasing the number of siliques or/and the number of seeds per silique (Jankowski *et al*., 2016b; Kwiatkowski, 2012; Grzebisz *et al*., 2010; Yang *et al*., 2009). The results of foliar fertilization on affecting the thousand seed weight are ambiguous. Our study has not shown a significant impact of the fertilizer Phostrade® BMo application on the thousand seed weight of the tested winter oilseed rape cv. Chagall in any year of the study (Table 4). Previous studies showed only a tendency to increase 1000-seed weight after foliar application of the potassium (Szczepanek *et al*., 2016). Jankowski *et al*. (2016b) in turn showed the beneficial effects of foliar fertilizers on 1000-seed weight of winter oilseed rape.

CONCLUSIONS

1. Foliar application of the PK fertilizer solution with boron and molybdenum (Phostrade® BMo) in autumn (BBCH 15), in a dose of 5 $dm^3 \cdot ha^{-1}$ or 3 $dm^3 \cdot ha^{-1}$ stimulated the growth of dry weight and root length of the winter oilseed rape population cultivar Chagall before winter.
2. The effect of foliar application of the fertilizer on biometric features, yield structural elements and oilseed rape yield was higher in the year characterized by precipitation deficit in the period of spring growth and generative development.
3. Two-time application of the fertilizer in doses 3 $dm^3 \cdot ha^{-1}$ in autumn and 3 $dm^3 \cdot ha^{-1}$ in spring, as well as a one-time dose 5 $dm^3 \cdot ha^{-1}$ applied in autumn had a beneficial effect on the number of seeds per pod and oilseed rape yield, as well as on the chlorophyll index and dry weight of shoots measured at the end of flowering. Two-time application was the most beneficial for the number of pods per plant.

REFERENCES

Cheema, M.A., Sattar, A. Rasul, F., Saleem, M.F. (2012). Influence of different levels of potassium on growth, yield and quality of canola (*Brassica napus* L.) cultivars. Pak. J. Agr. Sci., 49, 163–168.

Fanaei, H.R., Galavi, M., Kafi, M., Bonjar, A.G. (2019). Amelioration of water stress by potassium fertilizer in two oilseed. Int. J. Plant Prod., 3, 41–54.

FAOSTAT. (2019). FAO Statistics Division. Available from: http://faostat3.fao.org/.

Grzebisz, W. (2011). Oilseed plants. [In:] W. Grzebisz (ed.), Crop fertilization – yield physiology. Part 1. Oilseed, root and legume crops. Poznań: PWRiL, 50–135.

Grzebisz, W., Łukowiak, G., Biber, M., Przygocka-Cyna, K. (2010). Effect of multi-micronutrient fertilizers applied to foliage on nutritional status of winter oilseed rape and development of yield forming elements. J. Elem., 15, 477–491.

Jankowski, K., Sokólski, M., Dubis, B., Krzebietke, S., Żarczyński, P., Hulanicki, P., Hulanicki, P. (2016a). Yield and quality of winter oilseed rape (*Brassica napus* L.) seeds in response to foliar application of boron. Agr. Food Sci., 25, 164–176.

Jankowski, K.J., Hulanicki, P.S., Krzebietke, S., Żarczyński, P., Hulanicki, P., Sokólski, M. (2016b). Yield and quality of winter oilseed rape in response to different systems of foliar fertilization. J. Elem., 21, 1017–1027.

Koeslin-Findeklee, F., Becker, M.A., Van Der Graaff E., Roitsch, T., Horst, E.J. (2015). Differences between winter oilseed rape (*Brassica napus* L.) cultivars in nitrogen starvation-induced leaf senescence are governed by leaf-inherent rather than root-derived signals. J. Exp. Bot., 66, 3669–3681.

Kwiatkowski, C.A. (2012). Response of winter rape (*Brassica napus* L. ssp. oleifera Metzg., Sinsk) to foliar fertilization and different seeding rates. Acta Agrobot., 65, 161–170.

Ma, B.L., Biswas, D.K., Herath, A.W., Whalen, J.K., Ruan, S.Q., Caldwell, C., Earl, H., Vanasse A., Scott, P., Smith, D.L. (2015). Growth, yield and yield components of canola as affected by nitrogen, sulphur and boron fertilization. J. Plant Nutr. Soil Sci., 178, 658–670.

Qin, S., Hu, Ch., Tan, Q., Sun, X. (2017). Effect of molybdenum levels on photosynthetic characteristics, yield and seed quality of two oilseed rape (*Brassica napus* L.) cultivars, Soil Sci. Plant Nutr., 63, 137–144.

Shi, W., Wang, X., Yan, W. (2014). Distribution patterns of available P and K in rape rhizosphere in relation to genotypic difference. Plant Soil, 261, 11–16.

Siwik-Ziomek, A., Szczepanek, M. (2018). Soil enzyme activity and sulphur uptake by oilseed rape depending on fertilization and biostimulant application, Acta Agr. Scand. B-S P, 68, 50–56.

Soil Survey Staff. (2010). Keys to Soil Taxonomy, 11th ed., Washington, DC: USDA Natural Resources Conservation Sevice.

Szczepanek, M., Siwik-Ziomek, A., Wilczewski, E. (2017). Effect of biostimulant on accumulation of Mg in winter oilseed rape under different mineral fertilization rates. J. Elem., 22, 1375–385.

Szczepanek, M., Wilczewski, E., Grzybowski, K. (2016). Response of winter oilseed rape (*Brassica napus* L.) on soil applied humus preparation and foliar potassium fertilizer. Acta Sci. Pol. Agricultura, 15(4), 85–94.
Szczepaniak, W. (2015). The mineral profile of winter oilseed rape in critical growth stages – potassium. J. Elem. 20, 203–215.
Velicka, R., Marcinkeviciene, A., Raudonius, S., Rimkeviciene, M. (2016). Integrated evaluation of rape readiness for overwintering. Acta Agr. Scand. B-S P, 56, 110–116.
White, C.A., Eoques, S.E., Berry, P.M. (2015). Effects of foliar-applied nitrogen fertilizer on oilseed rape (*Brassica napus*). J. Agr. Sci., 153, 42–55.
Yang, M., Shi, L., Xu, F-S., Lu J-W., Wang, Y-H. (2009). Effects of B, Mo, Zn, and their interactions on seed yield of rapeseed (*Brassica napus* L.). Pedosphere, 19, 53–59.

TECHNOLOGIA UPRAWY RZEPAKU OZIMEGO Z WYKORZYSTANIEM NAWOŻENIA DOLISTNEGO

Streszczenie

Skuteczne strategie nawożenia są warunkiem koniecznym do zapewnienia optymalnego poziomu plonowania oraz jakości nasion rzepaku ozimego. Celem badań była ocena wpływu jesiennego lub jesiennego i wiosennego, dolistnego stosowania potasu, fosforu, boru i molibdenu (Phostrade® BMo) na cechy biometryczne, zimowanie oraz ilość i jakość plonu rzepaku ozimego. Przedmiotem badań była populacyjna odmiana rzepaku ozimego „Chagall", uprawiana w kolejnych latach 2013–2015, po pszenicy ozimej. Podstawą badań było jednoczynnikowe doświadczenie polowe, zlokalizowane w województwie kujawsko-pomorskim (53°13′ N; 17°51′ E). Zastosowano układ losowanych bloków, w czterech powtórzeniach. W doświadczeniu oceniano efekty aplikacji dolistnego nawozu Phostrade® BMo (P_2O_5 15% w/w, K_2O 14% w/w, B 0,9% w/w; Mo 0,1% w/w). Nawóz aplikowano w następujący sposób: 5 $dm^3 \cdot ha^{-1}$ jesienią w fazie pięciu liści rzepaku (BBCH 15) (T1) lub 3 $dm^3 \cdot ha^{-1}$ jesienią (BBCH 15) i 3 $dm^3 \cdot ha^{-1}$ wiosną na początku fazy wydłużania pędu (BBCH 30) (T2). Wykazano, że stosowanie nawozu jesienią, w dawce 5 $dm^3 \cdot ha^{-1}$ lub 3 $dm^3 \cdot ha^{-1}$ miało korzystny wpływ na wielkość suchej masy i długość korzeni rzepaku przed zimą. Wpływ dolistnego nawożenia na wielkość suchej masy pędów, liczbę łuszczyn na roślinie i liczbę nasion w łuszczynie, a także na plon rzepaku był większy w roku charakteryzującym się niedoborem opadów podczas wiosennego wzrostu i rozwoju generatywnego. Dwukrotne zastosowanie nawozu (jesienią i wiosną), a także jednorazowe zastosowanie jesienią miało korzystny wpływ na liczbę nasion w łuszczynie i plon nasion, a także na indeks chlorofilu i suchą masę pędów pod koniec kwitnienia. Zastosowanie Phostrade® BMo jesienią i wiosną, a także jednorazowa aplikacja jesienią zwiększyło plon nasion populacyjnej odmiany 'Chagall' rzepaku. Potrzebne są jednak dalsze badania w celu określenia optymalnej metody stosowania nawozu dolistnego Phostrade® BMo w uprawie odmian hybrydowych rzepaku ozimego.

Słowa kluczowe: cechy biometryczne, indeks chlorofilu, plon nasion, zawartość tłuszczu