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IMPACT OF FOUR-YEAR PERIOD APPLICATION OF PRP SOL AND PRP EBV ON THE YIELD AND QUALITY OF WINTER OIL SEED RAPE

Summary

Studies on the reaction of winter oil seed rape on the application of fertilizers PRP were carried out in 2012-2015, in the Department of Agronomy at the University of Life Sciences in Poznan, in the fields of the Experimental and Didactic Department Gorzyn in Złotniki Station. The aim of the study was to evaluate the influence of fertilization on yield and quality of winter oil seed rape during the four-year application of PRP SOL and PRP EBV. The results showed that the use of PRP SOL or PRP EBV separately, may lead to seed yield similar to that after fertilization with P and K. In turn, the use of PRP SOL with spraying of PRP EBV, compared with the control, significantly decreased seed yield on average by 2.86 dt·ha^{-1}. Fertilization with PRP SOL caused a similar fat content in dry weight of rape seeds like fertilization with conventional P and K. In turn, the use of PRP EBV alone or in combination with PRP SOL significantly decreased fat concentration. The application of PRP SOL in the cultivation of oil seed rape resulted in a significant reduction of the sum of glucosinolates and alkene glucosinolates in the dry matter of seeds. And the use of PRP EBV induced a tendency to increase the content of above substances
Key words: *winter oil seed rape, PRP SOL fertilizer, PRP EBV fertilizer, field experimentation*

WPŁYW CZTEROLETNIEGO OKRESU STOSOWANIA PRP SOL I PRP EBV NA PLONOWANIE I JAKOŚĆ NASION RZEPAKU OZIMEGO

Streszczenie

Badania nad reakcją rzepaku ozimego na stosowanie nawozów PRP prowadzono w latach 2012–2015 w Katedrze Agronomii Uniwersytetu Przyrodniczego w Poznaniu, na polach Zakładu Doświadczalno-Dydaktycznego Gorzyń, w Stacji Złotniki. Celem przeprowadzonych badań była ocena wpływu nawożenia na plonowanie i jakość nasion rzepaku ozimego w okresie czteroletniego stosowania PRP SOL i PRP EBV. Wyniki badań wykazały, że zastosowanie PRP SOL lub PRP EBV oddzielnie może prowadzić do uzyskania plonu nasion na podobnym poziomie jak po nawożeniu P i K. Z kolei zastosowanie PRP SOL wraz z opryskiem PRP EBV istotnie, w porównaniu z obiektem kontrolnym, obniżyło plon nasion, średnio o 2,86 dt·ha^{-1}. Stosując nawożenie PRP SOL uzyskano podobną zawartość tłuszczu w suchej masie nasion rzepaku jak po tradycyjnym nawożeniu P i K. Z kolei użycie PRP EBV oddzielnie lub łącznie z PRP SOL istotnie obniżało tę koncentrację. Wprowadzenie PRP SOL w uprawie rzepaku ozimego powodowało istotne obniżenie zawartości sumy glukozynolanów oraz glukozynolanów alkenowych w suchej masie nasion. Natomiast użycie PRP EBV wykazywało tendencję do wzrostu tych zawartości.
Słowa kluczowe: *rzepak ozimy, nawozy, PRP SOL, PRP EBV, badania polowe*

1. Introduction

Fertilization of plants of winter rape is a factor in agricultural technology, which has the biggest impact on the formation of the weight and quality of the rape seeds [7, 13]. Among the nutrients, nitrogen has a positive impact on growth and development, and has the greatest impact on the overall seed yield and protein as well as fat content. Phosphorus is involved in the biosynthesis of proteins, accelerates the development and flowering of plants [28]. On the other hand, potassium affects water management of plants, increases the efficiency of nitrogen fertilizers, and its dynamics of collection and accumulation by rape is significantly higher than other nutrients, as pointed out Grzebisz and Gaj [8], highlighting the major role of soil fertility in potassium and phosphorus. Supply of the soil not only in the basic ingredients, but also in calcium, magnesium, sulfur and trace elements (boron, manganese) is important in obtaining high and measurable yields. Nitrogen, magnesium and sulfur and trace elements are the components which move relatively easily in soil and can be quickly supplied to the plant as foliar fertilizers [5]. This way of feeding plants with the use of synthetic fertilizers is commonly used in conventional crops, while in organic farming, such fertilizers are not permitted. This is a serious problem, because very often these types of application aimed at improving the health of plants [6]. The inability to protect rape in the system of organic farming and the related uncertain yield make only a few farms in Poland, which have taken up such production. It should be noted increased interest in organic cultivation of rapeseed, which is associated with the growing consumer demand for organic products, including oil seed rape cold pressed. In neighboring countries (Germany, Czechia) growing organic winter oilseed rape is already a fact, while in Poland it is still at the stage of investigating the possibilities of protection of winter oilseed rape and are random and few, while they could also be used in the strategy of integrated crop production, the implementation of which is a necessity [15]. The introduction of alternative methods of plant protection may also be an opportunity to improve the quality of commodities. On the market there are modern preparations permitted for use in organic farming, an example of which is fertilizer PRP SOL (calcium and magnesium fertilizer) and PRP EBV (fertilizer with potassium, magnesium and sodium with the addition of copper) produced by PRP Technologies Polska. According to the manufacturer of fertilizer, PRP SOL is a granulate formed based on calcium and magnesium carbonates and active ingredients, and the PRP EBV is a concentrated solution of mineral nutrients for foliar spraying. Conducted to date studies indicate, that PRP SOL enhances the biological properties of the soil, promotes development of soil fauna and directly affects the amount of microorganisms [17, 22]. Most of the soil phosphorus is in the inaccessible form to plants as phosphates $FePO_4$ and $AlPO_4$, while potassium is locked in clay minerals and thanks to the activation of biological life in the soil, is followed by conversion of these compounds into forms available for the plants. In turn, the PRP EBV, as assured by the manufacturer, provides plants with specific minerals, which promote the increase in resistance to stress factors.

It is worth mentioning, that dose of calcium applied in Poland in the last 10 years, averaging at 40.5 $kg \cdot ha^{-1}$ [9] highly differs from the actual needs, because in this country the share of very acidic and acid soils exceeds 50% of agricultural land, but there are areas in which the share of the most acidic soils constitutes more than 80% of the area. For crops the effects of acidification are dangerous; moreover, it leads to a reduction in availability of plant nutrients, especially phosphorus, magnesium and molybdenum [11]. Citing the authors emphasize that on acidic soils magnesium occurs most often in the form inaccessible to plants.

The aim of the study was to evaluate the influence of fertilization on yield and quality of winter oil seed rape during the four-year use of PRP SOL and PRP EBV.

2. Materials and methods

In the Department of Agronomy at the University of Life Sciences in Poznan, in 2012-2015, studies were conducted to evaluate the yield of winter oil seed rape during the four-year application of fertilizers PRP SOL and PRP EBV, in the fields of experimental station Złotniki (52°29' N; 16°57'E) belonging to the Experimental and Didactic Department Gorzyń. Each year the trials were carried out on luvisol soils, soil complex belonging to complex 4 (very good rye), and the quality class IVa. Barley was forecrop. Tillage was performed in accordance with the proper cultivation technology of the species and the direction of use. The trial was established as mono factorial one, randomized block design with four replications. Factors included methods of fertilization:

- control: mineral P and K (80 kg $P \cdot ha^{-1}$, 120 kg $K \cdot ha^{-1}$)
- PRP EBV in spray form on plants fertilized with minerals (PK+PRP EBV- 2 $l \cdot ha^{-1}$);
- PRP SOL (220 $kg \cdot ha^{-1}$);
- PRP SOL and PRP EBV as additional spray.

The dose of nitrogen fertilizer was 120 kg $N \cdot ha^{-1}$ and did not differentiate over experimental objects. During the vegetation phase BBCH 71-75 it was evaluated the nutritional status of plants with nitrogen (SPAD) using N-Tester Hydro, LAI using the meter SunScan Canopy Analysis System type SSI and plant height was measured. In addition, measurements were made of soil compaction using a manual penetrometer Penetrologger SN, manufactured by Eijkelkamp. In the spring after the start of vegetation it was evaluated winter survival of plants, expressed as percentage of the plants survived. After harvest, there were evaluated seed yield, number of pods per 1 m^2, the number of seeds per pod, 1000-kernel weight (TKW), moisture, hectoliter weight. With the use of device FOSS NIR Systems it was determined content of protein, fat, fiber acid-detergent (ADF), natural-detergent fiber (NDF), total glucosinolates and alkene glucosinolates in the dry weight of seeds. The contents of individual components are expressed in % of dry matter and in $\mu M \cdot g^{-1}$ of seed. Analyses were performed in the laboratory of Plant Breeding Strzelce Sp. o.o. branch Małyszyn.

The results from the years 2012-2015 were statistically analyzed using analysis of variance for the experience factor orthogonal in a randomized block design. The significance of differences was determined by Tukey's test at $p \leq 0.05$.

3. Results and discussion

Precipitation and temperature conditions in 2012-2015 varied and in particular months differed from the average of the multi-year (Tab. 1 and 2). In the years of study there was no period observed in which from April to July occurred full coverage of water needs of rape identified by Klatt [14]. Only in 2014, in which beyond June, water needs in the remaining months were satisfied. In all the years of research at planting and during the autumn vegetation, the total precipitation was within the requirements limits for rape, allowing germination, thereby establishing a predetermined plant density. Thermal conditions especially during the winter dormancy of plants in all years of the study allowed for winter survival of plants. Difficult period for overwintering of rape plants occurred in February 2012, in which there were absence of snow cover and frosts, as well as in the period from January to March 2013, when recorded temperatures were lower than in the multi-year period.

Compactness of soil can have a significant impact on the penetration of roots and the compacted layer may help to slow their growth, leading to limit the growth of plants and their higher vulnerability to drought [20]. The root system of winter oil seed rape well overcomes the resistance of the medium soil, so it yields high on soils plowed not so deep. Research indicates that rape sown directly into stubble yields statistically at the same level of cultivated after plowing [4]. Biological agents are designed to produce a significant activation of biological processes in the soil, the effect of which is to change the soil structure and its physical properties [10]. The four-years use of PRP SOL in winter oilseed rape resulted in reducing soil compaction, which was observed in all layers of measurement, and the difference compared to the control proved layer of 10-20 cm (Tab. 3). Similar results were obtained, when measured at a depth of 10, 20 and 30 cm, and the differences have been proven at depth of 10 cm (Tab. 4). These results confirm those earlier obtained in a five-year experiment with oilseed rape, which also showed a positive reaction of PRP SOL on the soil properties [31]. Also Piskier [25] showed that the use of EM1 resulted in a decrease in compactness in the layer of 10-15 cm, and it was smaller than that identified on the objects of control by 26%, but the difference is not statistically proven.

Table 1. Air temperature in 2012-2015 (meteorological data from experimental station Złotniki)
Tab. 1. Temperatura powietrza w latach badań 2012-2015 (dane meteorologiczne ze stacji doświadczalnej Złotniki)

Months *Miesiące*	Years / *Lata*				Average from multi-year *Średnia z wielolecia*
	2012	2013	2014	2015	
I	2,2	-2,4	-1,4	1,8	-1,4
II	-1,4	-0,3	3,5	1,0	-0,2
III	5,6	-2,3	6,7	5,2	3,5
IV	9,0	8,0	10,6	8,3	8,7
V	15,1	14,4	13,3	12,9	14,3
VI	15,8	17,3	15,9	15,7	17,5
VII	19,0	19,6	21,4	19,1	19,3
VIII	18,3	18,7	17,3	22,3	18,5
IX	14,1	12,4	15,2	14,5	13,9
X	8,3	10,3	10,8	7,7	9,1
XI	5,2	4,9	5,7	5,9	3,8
XII	-1,5	2,6	1,6	0,0	0,0
Average / *Średnia*	9,1	9,8	10,1	8,4	8,9

Source: own work / *Źródło*: praca własna

Table 2. Sum of precipitation in 2012-2015 (meteorological data from experimental station Złotniki)
Tab. 2. Sumy opadów atmosferycznych w latach badań 2012-2015 (dane meteorologiczne ze stacji doświadczalnej Złotniki)

Months *Miesiące*	Years / *Lata*				Average from multi-year *Średnia z wielolecia*
	2012	2013	2014	2015	
I	86,6	43,6	40,3	38,2	30,3
II	52,0	41,3	12,6	11,8	27,5
III	11,8	33,8	60,0	46,2	31,5
IV	25,0	17,4	57,2	18,4	31,5
V	58,0	81,0	92,4	36,2	50,0
VI	124,4	106,0	42,4	82,0	57,4
VII	149,4	46,2	46,6	65,0	74,9
VIII	56,4	44,2	89,8	25,2	55,8
IX	30,4	74,8	45,8	23,6	45,6
X	32,8	16,4	13,4	25,8	35,1
XI	28,6	47,4	17,4	55,4	36,0
XII	22,9	28,8	43,0	0,0	38,9
Total / *Suma*	678,3	580,9	560,9	346,6	514,5

Source: own work / *Źródło*: praca własna

Table 3. Compactness of three soil layers (MPascale)
Tab. 3. Zwięzłość trzech warstw gleby (MPascale)

Specification *Wyszczególnienie*	Soil layer / *Warstwa gleby*		
	0-10 cm	10-20 cm	20-30 cm
Control / *Kontrola*	0,55 a	1,12 a	1,60 a
PRP-SOL	0,54 a	0,93 b	1,44 a

Source: own work / *Źródło*: praca własna

Table 4. Compactness of three soil depths (MPascale)
Tab. 4. Zwięzłość gleby oceniona na trzech głębokościach (MPascale)

Specification *Wyszczególnienie*	Depth / *Na głębokości*		
	10 cm	20 cm	30 cm
Control / *Kontrola*	0,94 a	1,21 a	2,23 a
PRP-SOL	0,82 b	1,05 a	2,13 a

Source: own work / *Źródło*: praca własna

Table 5. Winter survival of plants, hectoliter weight and seed moisture at harvest
Tab. 5. Przezimowanie roślin, masa hektolitra oraz wilgotność nasion przy zbiorze

Specification *Wyszczególnienie*	Winter survival % *Przezimowanie %*	Hectolitre weight kg/hl *Masa hektolitra* kg/hl	Moisture % *Wilgotność %*
Control / Kontrola	46,0 b	66,1 a	8,3 a
PRP EBV	57,0 a	65,9 a	8,2 a
PRP SOL	62,0 a	60,7 b	8,2 a
PRP SOL+PRP EBV	60,1 a	59,0 b	8,0 a

Source: own work / *Źródło*: praca własna

Table 6. Plant height and LAI, PAR and SPAD
Tab. 6. Wysokość roślin oraz LAI, PAR i SPAD

Specification *Wyszczególnienie*	Plant height cm *Wysokość roślin cm*	LAI	PAR	SPAD
Control / *Kontrola*	126,2 a	2,35 ab	122,4 b	714,7 b
PRP EBV	131,0 a	2,01 b	137,0 a	729,9 a
PRP SOL	126,8 a	2,69 a	116,9 b	713,7 b
PRP SOL+PRP EBV	120,8 a	2,45 ab	134,7 a	744,6 a

Source: own work / *Źródło*: praca własna

Table 7. Yield and yield components in 2012-2015
Tab. 7. Plon i składowe plonu w latach badań 2012-2015

Specification *Wyszczególnienie*	Seed yield *Plon nasion* $dt \cdot ha^{-1}$	MTN TKW g	Pods per plant *Liczba łuszczyn na roślinie*	Seeds per pod *Liczba nasion w łuszczynie*	Pods per $1m^2$ *Liczba łuszczyn na* $1m^2$
Control / *Kontrola*	37,28 a	6,14 a	173,12 a	22,8 a	6544,0 b
PRP EBV	38,34 a	6,14 a	187,12 a	22,9 a	7374,0 a
PRP SOL	37,42 a	6,0 a	184,5 a	23,1 a	6167,5 b
PRP SOL+PRP EBV	34,36 b	6,0 a	154,5 b	23,8 a	5712,0 c

Source: own work / *Źródło*: praca własna

Table 8. Chemical composition of oilseed rape
Tab. 8. Skład chemiczny nasion rzepaku

Specification *Wyszczególnienie*	Fat *Tłuszcz* %	Protein *Białko* %	ADF %	NDF %	*Sum of alkene glucosinolates Suma gluko-zynolanów alkenowych (µM/g nasion)*	*Sum of glucosinolates Suma gluko-zynolanów (µM/g nasion)*
Control / *Kontrola*	44,53 a	19,49 b	20,49 a	20,80 a	5,52 a	9,39 a
PRP EBV	43,75 b	19,68 ab	20,56 a	20,65 a	5,84 a	9,71 a
PRP SOL	44,12 a	19,62 ab	20,55 a	20,62 a	3,62 c	7,27 c
PRP SOL+PRP EBV	43,82 b	19,82 a	20,71 a	20,29 a	4,56 b	8,27 b

Source: own work / *Źródło*: praca własna

The winter survival of oil seed rape plants is affected by long periods with low values of air temperatures (<-10°C), in the absence of snow cover [2]. The observations of Bartoszek [3] showed that the greatest frost damage during the winter was observed on the plantations where the soil temperature at a depth of 5 cm fell below -3°C and maintained for 15 days or longer. During experimental period, so difficult conditions for overwintering were not observed. On average, in the years of research, the PRP technologies used for fertilization significantly influenced of winter survival of plants (Tab. 5). The best winter survival was observed on plants fertilized with PRP SOL and the difference compared to the fertilized traditionally amounted to 16% points. In previous years 2008, 2009, 2011, when similar assessment was carried out, it was found only a trend toward better winter survival of plants fertilized with PRP SOL [31]. With the introduction of PRP it appeared slight tendency to decrease seed moisture at harvest, and the difference in relation to the control amounted to 0.1 (EBV PRP and PRP SOL) and 0.3% points (PRP SOL+ PRP EBV) (Tab. 5). Similar results occurred in the study of winter wheat and spring barley [29], while the use of PRP SOL in the cultivation of oilseed rape and maize resulted in a slight extension of vegetation expressed as an increase in seed moisture [31,32]. The use of PRP SOL, and PRP SOL with PRP EBV spray led to a significant decrease in hectoliter weight, which compared with the control was 5.4 and 7.1 $kg \cdot hl^{-1}$ (Tab. 5). In recent years, the use of PRP SOL caused a similar response in oil seed rape - hectoliter weight decrease relative to the control was 0.3 $kg \cdot hl^{-1}$ and was not statistically significant [31]. In turn, fertilizer used in maize caused a tendency to increase the value of the discussed feature [32].

Introduction to agricultural sciences of non-destructive measurement methods, such as test SPAD (Soil Plant Analysis Development) or determination of Leaf Area Index (LAI), allow to maximize the information obtained about the reaction of plants to different conditions of environment, as well as they are useful to determine fertilizer needs [18]. Many authors show that between these indicators and selected indicators of physiological and biometric features and the yield, there are undergoing significant dependences [23,38]. Piekarczyk et al. [24] on the basis of specific indicators of vegetation observed differences in the development of oilseed rape resulting from the reaction of plants on the analyzed experimental factors - nitrogen fertilization, cultivar. Leaf area index (LAI) is a multiple of the leaf area relative to the area occupied by crop field and is the most commonly used measure to evaluate the growth and biomass accumulation [26]. In our study, regardless of the technology used for fertilization, LAI average value was 2.4, which means that no theoretical maximum efficiency of photosynthesis and the maximum seed yield, because by Suohu et al. [34] the optimal LAI value for oil seed rape should be in the range of 4 - 4.5. After application of PRP SOL, LAI value increased by 0.34 as compared to control, but this difference was not statistically significant (Tab. 6). Also in previous studies conducted on maize and potatoes, they noticed a similar trend [30,32]. In turn, oilseed rape average in 2007-2011, responded to PRP SOL in opposite way - LAI value decreased on average by 0.2 as compared to control, but these results were not statistically proven [31].

LAI characterizes assimilation surface capable of absorbing PAR, which determines the photosynthesis, and indirectly, the increase in biomass [19], therefore PAR is considered as the second, important indicator of photosynthetic productivity of plants. In the absence of environmental stress, plants can produce in photosynthesis process 90% of dry matter, and its output is a linear function of PAR, so that plants showing higher PAR produce more dry matter for a longer period of the growing season [27]. Maximum values of PAR showed rape plants that received the full technology of PRP (PRP SOL + PRP EBV) and spraying with PRP EBV alone.

The use of PRP in full fertilization technology with PRP EBV spray had a positive impact on nutritional status. The obtained SPAD value was at a similar level as in the experiments by Wójtowicz et al. [37] at the highest tested dose of nitrogen of 220 kg $N \cdot ha^{-1}$. The use of PRP SOL without additional PRP EBV spray resulted in SPAD values at a similar level as the control, whereas in previous studies on the use of this fertilizer it was observed a significant improvement in the nutritional status of oilseed rape, winter wheat, spring barley and potatoes [29,30,31]. There was not noticed the effect of PRP technology fertilization on plant height. Spraying with PRP EBV in addition to the plants fertilized with minerals, their height increased by 4.8 cm, but the difference was not statistically significant (Tab. 6).

During the four-year study it was shown that winter oilseed rape can be interchangeably fertilized with mineral fertilizer P and K, and with PRP SOL. Seed yield obtained from plants fertilized with PRP technology was comparable with the yield obtained from plants fertilized with traditional P and K (Tab. 7). There has been a slight, statistically not proven increase in seed yield after separate use EBV PRP and PRP SOL, which amounted, compared to the control, respectively to 1.06 and 0.14 $dt \cdot ha^{-1}$. Rape has a very high calcium requirement – intakes more than 200 $kg \cdot ha^{-1}$ at the yield of 4 t of seeds [1]. With the dose of 220 $kg \cdot ha^{-1}$ PRP SOL it is introduced into the soil 70.4 $kg \cdot ha^{-1}$ CaO and 17.6 $kg \cdot ha^{-1}$ MgO, which at such high nutritional needs of this species could be the cause of not getting much effect. It should be noticed that the use of a complete fertilization technology (PRP SOL + PRP EBV) results in a significant reduction in seed yield, on average by 2.92 $dt \cdot ha^{-1}$. In previous experiments with winter oilseed rape during the five-year testing of fertilizer PRP SOL it has not been confirmed yield influencing effect of the use of PRP SOL in oilseed rape [31]. This fertilizer used in the cultivation of potatoes, wheat and maize led to an increase in the yield of these crop species [29, 30, 32].

The decrease in seed yield after application of PRP SOL with PRP EBV spray was mainly observed in reducing the number of pods per plant and per area of 1 m^2, and the differences in relation to the control amounted to 18.62 and 832 pcs respectively. Many authors conclude, that achieving of increase in the number of pods per plant is the direct cause of increased seed yield of rapeseed, which is best obtained by increasing the mineral NPK fertilization [21, 36].

The use of mineral fertilizers and PRP EBV spray caused a tendency to increase seed yield, which compared with the control amounted on average in four years to 1.06 $dt \cdot ha^{-1}$. In turn, the yield of the combination in which SOL PRP was at the level of the control.

The values of the weight of 1000 seeds ranged from 6.0 g for the objects fertilized with PRP SOL or PRP SOL+PRP EBV to 6.14 g for other objects, but these differences were not statistically confirmed. Also the number of seeds per pod did not depend significantly on the used combination of fertilizer and ranged from 22.8 for the control object to 23.8 after the use of PRP SOL + PRP EBV. Similarly in previous studies, by the use of PRP SOL, no significant differences in the values of these traits have been observed in the cultivation of oilseed rape [31]. The use of this fertilizer did not influence significantly the weight of 1000 grains of spring barley and the number of grains of maize ear [29, 32].

The number of pods per 1m^2 changed significantly depending on the fertilization. Lower values than in other objects have been observed in the control object (6544.0) and after the use of PRP SOL (6167.5). Significantly higher values than in those objects were found after PRP EBV (7374.0), in turn, significantly lower after application of both tested fertilizers together (5712.0).

Many authors showed that the chemical composition of oilseed rape is formed mainly under the influence of genetic and environmental factors [16,34], and among the agronomic factors, to the greatest extent nitrogen and sulfur fertilization determine protein and fat content in the seeds [12,38]. Application of rape with PRP SOL, compared with the control, has not changed significantly the fat content in the dry weight of seeds. On the other hand, spraying with PRP EBV on plants fertilized with NPK resulted in lower accumulation of fat in the seeds, and the difference relative to the control was 0.78% points and was statistically significant. The protein content in seeds increased when PRP technology was used and the most statistically significant increase was observed after the application of PRP SOL with PRP EBV spray - difference relative to the control was 0.33% points. In the studies, there was no impact of technology of fertilization with PRP on acid-detergent fiber content (ADF) and neutral-detergent fiber (NDF) (Tab. 8).

The glucosinolate content in seeds determines the usefulness and fodder value of rapeseed meal. Many researchers warn against excessive sulfur fertilization, which greatly increases the amount of undesirable compounds in seeds [38]. The application of PRP SOL fertilizer caused a significant decrease in the total concentration of glucosinolates and alkene glucosinolates content and the differences from control were respectively 2.12 and 1.9 $\mu M/g$ of seeds. The preferred reduction in glucosinolate content in rapeseed was also obtained after the application of both tested fertilizers together, but the differences from the control treatment were significantly smaller. In the last study period, there was no positive effects of PRP SOL on the quality of seeds. Application of this fertilizer caused the opposite reaction and increased total glucosinolate content on average by 0.65 $\mu M/g$ of seeds compared to control [31]. The reason for obtaining contradictory results could be in different weather conditions that significantly modify the content of these components in rapeseed. In studies by Wielebski [34] conducted in the conditions of a wet spring, glucosinolate content in seeds was significantly higher than in the years when it was recorded large shortage of water during this period.

4. Conclusions

1. Application of PRP SOL fertilizer to the soil loosened all tested layers, and significantly reduced the soil compaction in the layer of 10-20 cm.
2. A four-year results showed that the use of PRP SOL or PRP EBV separately can result in seed yield at a similar level as the fertilization with P and K. On the other hand, the use of PRP SOL with PRP EBV spray significantly, compared with the control, decreased seed yield, on average by 2.86 $dt \cdot ha^{-1}$.
3. Application of SOL PRP fertilization caused similar fat content in dry weight of rape seeds as in the case of conventional P and K fertilization. In turn, the use of PRP EBV alone or in combination with PRP SOL significantly decreased the concentration of fat.
4. The application of PRP SOL in the cultivation of winter oilseed rape resulted in a significant reduction of the sum of glucosinolates and alkene glucosinolates in the dry matter of seeds. The application of PRP EBV caused a tendency to increase the content.

5. References

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