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# RESPONSE OF MAIZE TO USE THE PRP SOL AND PRP EBV FERTILIZERS

*Summary*

*Studies on the response of maize to use PRP fertilizer was carried out in 2012-2015 in the Department of Agronomy at the University of Life Sciences in Poznan, in the fields of the Experimental Station Gorzyń in Złotniki. Replacement of the traditional maize fertilization with phosphorus and potassium by PRP technology, both full (PRP SOL with PRP EBV) and the PRP SOL led to a significant increase in grain yield. This increase depending on the combination of fertilizer was 6.9 and 5.0 dt · ha$^{-1}$ for PRP SOL used with PRP EBV and alone PRP SOL, respectively. A similar positive effect of the use of PRP fertilizers was obtained for the yield of protein and starch. The confirmation of a positive response to this fertilization technology was also an increase in the value of features such as leaf area index, plant height and weight of 1000 grains. In addition, objects with application of fertilizer PRP SOL alone and PRP SOL with PRP EBV spraying, noted significantly lower affection of plants by Fusarium fungi.*
***Key words****: maize, PRP SOL fertilizer, PRP EBV fertilizer, grain yield, yield components*

# REAKCJA KUKURYDZY NA STOSOWANIE NAWOZÓW PRP SOL I PRP EBV

*Streszczenie*

*Badania nad reakcją kukurydzy na stosowanie nawozów PRP prowadzono w latach 2012–2015 w Katedrze Agronomii Uniwersytetu Przyrodniczego w Poznaniu, na polach Zakładu Doświadczalno-Dydaktycznego Gorzyń, Stacji w Złotnikach. Zastąpienie nawożenia tradycyjnego w uprawie kukurydzy nowoczesną technologią PRP, zarówno pełną jak i samym PRP SOL prowadziło do istotnego wzrostu plonu ziarna. Wzrost ten w zależności od technologii nawożenia wyniósł średnio 6,9 i 5 dt·ha-1 odpowiednio dla PRP SOL z opryskiem PRP EBV i PRP SOL. Podobny pozytywny efekt stosowania nawozów PRP uzyskano dla plonu białka i skrobi. Dowodem pozytywnej reakcji roślin na nowoczesną technologię nawożenia był także wzrost wartości badanych cech takich jak: indeks powierzchni liści, wysokość roślin i masie 1000 ziaren. Ponadto, na obiektach gdzie zastosowano sam nawóz PRP SOL oraz PRP SOL z opryskiem PRP EBV zauważono istotnie mniejsze porażenie roślin przez grzyby z rodzaju Fusarium.*
***Słowa kluczowe****: kukurydza, nawóz PRP SOL, nawóz PRP EBV, plon ziarna, komponenty plonowania*

## 1. Introduction

Technology of fertilization proposed by PRP Technologies Polska is based on the method of activation of cell metabolism MIP (Mineral Inducer Process), involving the stimulation of certain physiological functions of plant cells and animal organisms with specific minerals, of which the chemical composition and form are patented [21]. PRP SOL through its influence on soil structure and stimulation of biological life in it, is designed to provide huge amounts of nutrients that are so far in unavailable forms for plants [14]. Moreover, literature reports indicate that the fertilizer contains adjuvants, comprising microorganisms that guide the processes occurring in the soil, but is emphasized that the magnitude of the stimulation depends mainly on the species of cultivated plant [1, 21]. There are studies in which this effect is not confirmed [18]. Full technology of fertilizing proposed by the manufacturer is PRP SOL fertilizer applied with spraying of PRP EBV (currently Agri Opti Sunset). According to the manufacturer, PRP SOL is a granulate based on calcium and magnesium carbonates and active ingredients with appropriate technology MIP, while the PRP EBV is a concentrated solution of mineral foliar spraying, containing potassium, sodium, magnesium, copper and other trace elements. The use of calcium carbonate and magnesium places PRP SOL as the type of calcium-magnesium fertilizer, and PRP EBV in a type of fertilizer containing potassium, magnesium and sodium with the addition of copper. Additionally, PRP EBV can be used in organic farming in accordance with the Certificate of Qualified Product of 9 September 2005, issued by IUNG. In 2015 it was registered in France as a biostimulant. The aim of this technology is the intensification of crop production in compliance with the vital functions of soil ecosystem, which is part of a strategy of sustainable agriculture. It is especially important in the case of maize with great yield potential and significant nutrient needs [7].

Thus the aim of the study was to test the response of maize plants to different fertilization, including the possibility of replacing the traditional fertilization with phosphorus and potassium by PRP technology.

## 2. Materials and methods

The study was conducted in 2012-2015 in the Department of Agronomy at the University of Life Sciences in Poznań, in the fields of the Experimental Station Gorzyń in Złotniki (52°29’ N; 16°57’ E). The experiments were established in randomized block design with four replications plots. Testing factor was fertilizer combinations (Tab. 1):

- traditional fertilization (NPK) (control);
- fertilization with PRP EBV spray on plants fertilized with mineral forms (NPK+PRP EBV);
- fertilization with PRP SOL;
- fertilization with PRP SOL followed by PRP EBV spray.

In experiments on the combinations 1 and 2, the uniform phosphorus-potassium fertilization was applied at the dose of 80 kg P · $ha^{-1}$ and 120 kg K · $ha^{-1}$. PRP SOL fertilizer was applied at a dose of 220 kg · $ha^{-1}$ and PRP EBV spray at a dose of 2 l $ha^{-1}$ in the phase of 4-6 leaves (BBCH 14 to 16). The nitrogen was applied in all tested objects at the dose of 160 kg ·$ha^{-1}$.
In all the years of research forecrop for maize was wheat.

The soil of experimental field belonged to luvisoils, complex 4 (very good rye) quality class IVa. After completion of plant growth, at phase of BBCH 83-85, it was determined leaf area index (LAI) with a meter SunScan Canopy Analysis System type SSI. It was also measured the plant height and nutritional status - plant supply with nitrogen (SPAD) using N-Tester Hydro and the number of ears/$m^2$. After harvesting it was determined grain yield, 1000 grains weight (TKW), number of grains in a cob, grain moisture and hectolitre weight. In the laboratory of the Department of Agronomy it was determined total protein content in grain (Kjeldahl method determined by multiplying after hydrolysis, distillation and titration the total nitrogen content by 6.25 factor, which expresses the average nitrogen content in proteins) and the starch content (by the polarimetric method, according to Ewers). Weather conditions are presented based on meteorological data recorded daily in the station in Złotniki. Hydrothermal Sielianinow K factor [19] was calculated according to the formula $K = (P \cdot 10)/(T \cdot L)$, where K - hydrothermal Sielianinow factor, P - total monthly precipitation, T - average temperature of the month, L – number of the days of the month (Fig. 1). The results were statistically analyzed using analysis of variance for the orthogonal factorial experiments in a randomized block design. The significance of differences was determined by Tukey's test at $p \leq 0.05$.

## 3. Results and discussion

Among many environmental factors such as temperature, precipitation, light intensity or soil fertility, the greatest impact on the relative chlorophyll content determined with the help of the SPAD in maize plants, have nitrogen fertilization and measurement time [16]. Machul and Jadczyszyn [16] observed that SPAD test is useful in maize to determine the optimum supply of nitrogen in stage of 10 leaves and tassel flowering. The critical value for the test done by the authors on variety Costella amounted 538 units in phase of 10 leaves and 643 units in the phase of full tassel flowering. The results of our own experiments show a high state of nitrogen supply both in control object, as well as in PRP fertilizers. The use of PRP technology average in the years of the study had no significant impact on the nutritional status of maize plants, expressed in SPAD units, and their value ranged from 797.4 (PRP SOL + PRP EBV) to 802.8 (NPK + PRP EBV) (Tab. 2). In previous studies, there was an increase of SPAD after applying fertilizer PRP SOL in the cultivation of potatoes [25], winter oil seed rape [26] and winter wheat and spring barley [24]. The increase in SPAD value after application of PRP SOL was also demonstrated in the current study presented, but only as a trend.

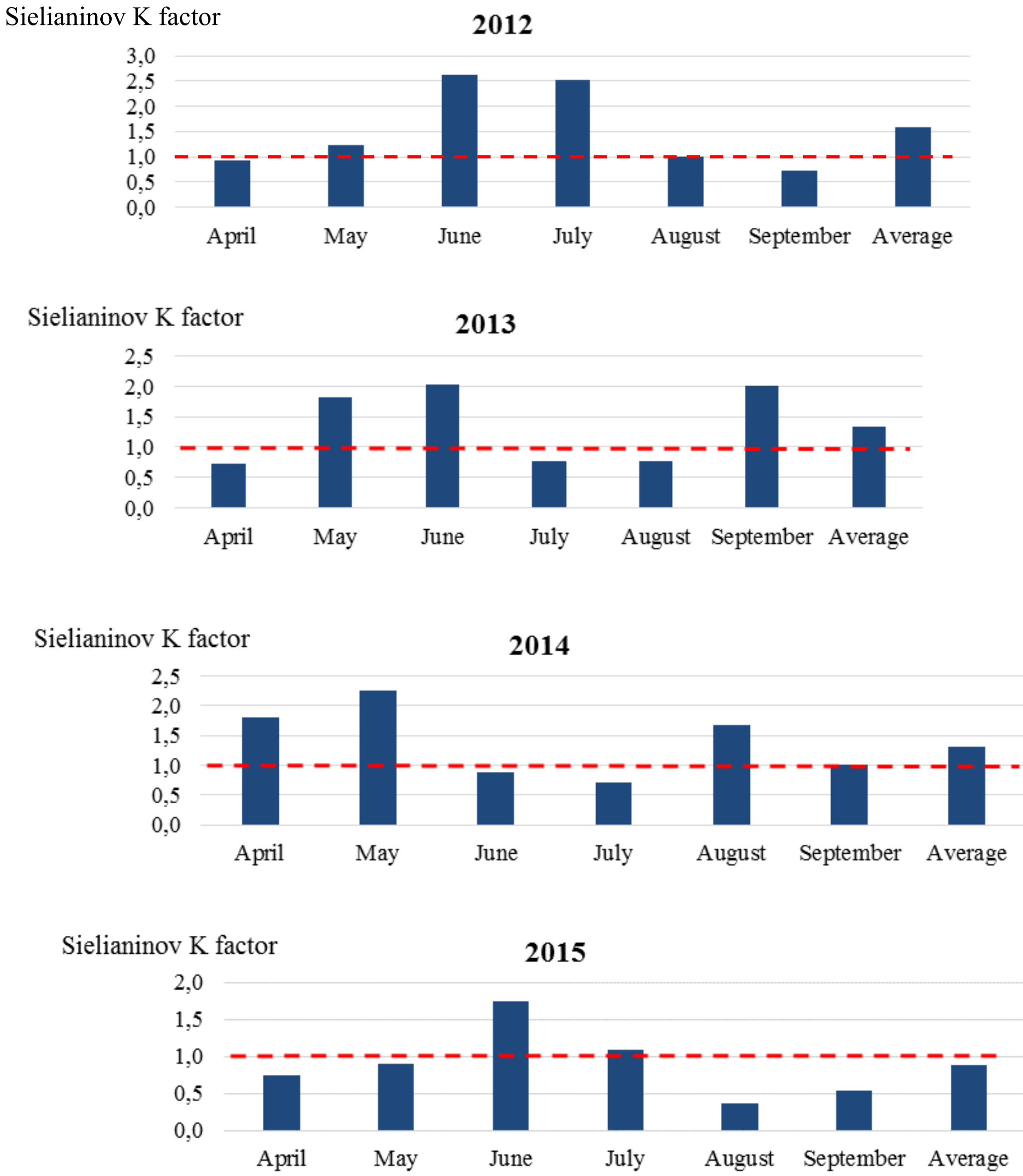
Determination of leaf area index (LAI), is like a SPAD test a nondestructive measurement method, which also allows to increase the amount of information obtained about the response of plants to different habitat conditions. In studies of Gołębiowska and Sekutowski [9], for example, the sensitivity of maize to herbicides used in conditions of long lasting drought and cold, confirmed the low indexes LAI of 1.8 - 2.6. According to the authors, the losses in the yield of maize grain due to applied herbicides can be foreseen in advance with the use of LAI. Our findings do not confirm this relationship, but it may be due to the diversity of weather conditions in the years of research, because every year there were months with insufficient water content in the soil, and the last year of the research was particularly difficult in terms of supply of plants in the water. Similarly, the studies of Biskupski et al. [3] showed no significant difference between the yield and the surface of the leaves (LAI). The subsequent works of the authors [2] indicate, that at too high values of LAI, worse light conditions and supply plants in $CO_2$, as well as increased susceptibility to infection diseases and attacks by pests occur. The conditions under which the test was carried out allowed to establish the largest maize leaf area per unit area after the application of fertilizer PRP SOL (3.3) (Tab. 2). This value is below the optimum LAI level (4.0) for cereal defined by Czerednik and Nalborczyk [6]. However, it was higher than determined in the present study on the control object by 0.3 and by 1.3 units higher than in studies Biskupski et al. [2]. Similar to those obtained in the present study the LAI = 3.0 for maize also observed Szulc and Waligóra [30] after application of 120 kg N·$ha^{-1}$. Own results are consistent with those obtained previously for maize [27] and potato [25] where the use of PRP SOL has shown a trend to a small increase of LAI values compared to the control, while the wheat and barley [24] and rape [26] responded opposite to this fertilizer because it was found a statistically insignificant decrease of this index.

Plants fertilized with PRP SOL were higher than in the control object, and the difference was an average of 2.2 cm but was statistically insignificant. Only additional spraying with PRP EBV, used both with mineral fertilizers and PRP SOL, caused a significant increase of maize plants height by 10.4 and 5.8 cm, respectively. In previous studies of maize, winter wheat and spring barley there was no significant effect of PRP SOL on plant height [24, 27], whereas after applying of PRP SOL, there was increase of rape plants height by an average of 4.8 cm [26]. Bogucka et al. [4] obtained the highest maize plants (240.3 cm) after application of 270 kgN·$ha^{-1}$. At this dose of nitrogen maize ears were established at a height of 84.1 cm. In our study this height was larger on average by 48.2 cm, regardless of the fertilization technology used (Tab. 2).

Table 1. Type of fertilizers applied and its composition
*Tabela 1. Skład i rodzaj nawozów wnoszonych pod kukurydzę*

| Fertilizer type | Composition |
|---|---|
| Potassium salt<br>Triple superphosphate<br>Ammonium nitrate | $K_2O$ (60%)<br>$P_2O_5$ (46%)<br>N (32%) |
| PRP SOL granulate | CaO (35%), MgO (8%) + MIP (compounds of Fe, Zn, B, Na, Mn and others) |
| PRP EBV liquid | $K_2O$ (3.5%). $N_2O$ (1.4%). MgO (0.42%). Cu (0.02%) and S, Mn, B |

*Source*: own work / *Źródło*: praca własna




Interpretation of Sielianinov's hydrothermal coefficient:
K > 1.5. moisture for all plants excessively wet
K = 1.0 - 1.5; sufficient moisture
K = 0.5 - 1.0; insufficient moisture
K < 0.5 moisture less than the requirement for most of plants - drought

*Source*: own work / *Źródło*: praca własna

Fig. 1. Sielianinov hydrothermal coefficient according to weather conditions from April to September at Experimental Station Złotniki in 2012-2015

*Rys. 1. Hydrotermiczny współczynnik Sielianinov na podstawie warunków pogodowych ze stacji Doświadczalno-Dydaktycznej Złotniki (od kwietnia do września) w latach 2012-2015*

Table 2. Biometric characters of maize plants depending on fertilization in 2012-2015

*Tabela 2. Cechy biometryczne roślin kukurydzy w zależności od nawożenia zastosowanego w latach 2012-2015*

| Fertilization / *Nawożenie* | Nitrogen nutritional status (SPAD) / *Stan odżywienia roślin azotem* | Leaf area index (LAI) / *Indeks powierzchni liści* | Plant height (cm) / *Wysokość roślin* | Ears height (cm) / *Wysokość osadzenia kolb* |
|---|---|---|---|---|
| Kontrola/ *Control* NPK | 782,3 a* | 3,0 c | 254,2 a | 130,6 a |
| NPK + PRP EBV | 802,8 a | 2,4 b | 264,6 c | 136,7 b |
| PRP SOL | 801,2 a | 3,3 d | 256,4 ab | 129,0 a |
| PRP SOL + PRP EBV | 797,4 a | 2,2 a | 260,0 bc | 133,1 ab |
| **Average / *Średnio*** | **795,9** | **2,7** | **258,8** | **132,3** |

*a, b, c - homogeneous groups

*Source*: own work / *Źródło*: praca własna

Table 3. Percentage of plants with symptoms of common smut and Fusarium and damaged by corn borer, depending on fertilization in 2012-2015
*Tabela 3. Procent roślin z objawami głowni guzowatej kukurydzy i fuzaryjnej zgnilizny łodygi oraz uszkodzonych przez omacnicę prosowiankę w zależności od rodzaju zastosowanego nawożenia w latach 2012-2015*

| Fertilization / *Nawożenie* | Ustilago zeae Unger / *Głownia guzowata* | Fusarium spp. / *Fuzaryjna zgnilizna łodygi* | Ostrinia nubilalis / *Omacnica prosowianka* |
|---|---|---|---|
| Kontrola/ *Control* NPK | 8,7 a* | 5,8 b | 14,5 a |
| NPK + PRP EBV | 9,4 a | 4,2 b | 14,5 a |
| PRP SOL | 9,9 a | 2,0 a | 15,9 a |
| PRP SOL + PRP EBV | 10,4 a | 1,5 a | 12,9 b |
| **Average / *Średnio*** | **9,6** | **3,4** | **14,4** |

*a, b, c - homogeneous groups *Source*: own work / *Źródło*: praca własna

Table 4. Yields of grain, protein and starch depending on fertilization type applied in 2012-2015
*Tabela 4. Plony ziarna, białka oraz skrobi uzyskane w zależności od rodzaju zastosowanego nawożenia w latach 2012-2015*

| Fertilization / *Nawożenie* | Yield of maize grain ($dt \cdot ha^{-1}$) / *Plon ziarna* | Yield of protein ($kg \cdot ha^{-1}$) / *Plon białka/* | Yield of starch ($kg \cdot ha^{-1}$) / *Plon skrobi* |
|---|---|---|---|
| Kontrola/ *Control* NPK | 110,2 a* | 1149,1 a | 7404,9 a |
| NPK + PRP EBV | 109,5 a | 1148,3 a | 7455,5 a |
| PRP SOL | 115,2 b | 1214,8 b | 7986,4 b |
| PRP SOL + PRP EBV | 117,1 b | 1224,7 b | 7938,3 b |
| **Average / *Średnio*** | **113,0** | **1184,2** | **7696,3** |

*a, b, c - homogeneous groups *Source*: own work / *Źródło*: praca własna

Table 5. Yield components and other biometric characters depending on fertilization type applied in 2012-2015
*Tabela 5. Komponenty plonowania i pozostałe cechy biometryczne w zależności od rodzaju zastosowanego nawożenia w latach 2012-2015*

| Fertilization / *Nawożenie* | Ears number / *Liczba kolb* ($szt \cdot m^2$) | Number of kernels in ear / Liczba ziaren w kolbie (szt.) | TGW / *MTZ* (g) | Grain moisture (%) / *Wilgotność ziarna* | Hectoliter weight / *Masa hektolitra* ($kg \cdot hl^{-1}$) |
|---|---|---|---|---|---|
| Kontrola/ *Control* NPK | 8,6 a* | 441,1 a | 302,5 a | 26,2 a | 70,7 a |
| NPK + PRP EBV | 8,4 a | 454,5 a | 308,1 ab | 27,1 b | 74,6 a |
| PRP SOL | 8,7 a | 455,0 a | 310,1 b | 26,9 b | 74,1 a |
| PRP SOL + PRP EBV | 8,6 a | 462,7 a | 311,3 b | 26,4 a | 75,4 a |
| **Average / *Średnio*** | **8,6** | **453,3** | **308,0** | **26,6** | **73,7** |

*a, b, c - homogeneous groups *Source*: own work / *Źródło*: praca własna

Szymańska et al. [31] showed a significant difference in the percentage of infected plants by fungus *Ustilago zeae* depending on the weather. Sulewska et al. [28] showed the largest percentage of plants infected by this fungus (15.4%) in the year with hot and dry summer. On the contrary Szymańska et al. [31] showed that in dry and warm year the infection of the plants was negligible at 1.4%. In our study, the average percentage of infected plants by *U. zeae* amounted to 9.6% (Tab. 3). At objects where PRP technology was used, it was noted tendency to slight increase in the number of plants infected by the fungus causing common smut, especially in the object fertilized with PRP SOL with PRP EBV spraying (by 1.7% points more than in the control object). Similarly, using of PRP SOL, compared to control in studies of Szymańska et al. [31], did not significantly affect the range of infected plants. Piechota et al. [23] also found no increase of common smut and fusarium under the influence of different fertilization during the three-year study.

Our study showed a significant impact of PRP technology on the percentage of plants infected by fungi of *Fusarium*. The use of PRP SOL and PRP SOL with spraying of PRP EBV has reduced the percentage of infected plants compared to the control by 3.8 and 4.3% points. Szymańska et al. [31] explained the similar results by the fact that the objects fertilized with PRP SOL, compared to conventionally fertilized was better supply with potassium and phosphorus, which may help the plants to overcome the pressure of diseases. However, in studies of Szulc [29] presowing application of NPK significantly reduced the percentage of plants infected by the fungus *Fusarium spp.* compared to the PK fertilization before sowing of maize and N in the phase of 5-6 leaf (BBCH 15-16). These results were confirmed by Katan [12], who found that only under conditions of optimal plant nutrition with minerals the plant can run all defense mechanisms. Moreover, the object fertilized with PRP SOL and PRP EBV in our study, it was also recorded a smaller percentage of plants damaged by corn borer, which amounted to 12.9 and was lower by 1.6 % points compared to the control, and this difference was statistically significant.

Replacement of the traditional fertilization with a new technology had a positive effect on the yield of maize plants and fertilizing both with PRP SOL and PRP SOL + PRP EBV compared with the control allowed to significant increase in grain yield, which increased by 5 and 6.9 $dt \cdot ha^{-1}$ (Tab. 4). Also, in previous studies, PRP SOL fertilizer increased the yield of winter oilseed rape, potatoes, maize and wheat, respectively by 2.0; 15.9; 9.0; and 1.9 $dt \cdot ha^{-1}$ [24-27]. On the other hand, in earlier studies it was not observed a similar response to PRP SOL fertilization on spring barley [24].

Protein yield is a function of grain yield and protein content in it [10]. According to Kruczek and Bober [13] a large impact on the chemical composition of plants has soil and its richness in nutrients. In our study, the size of protein yield was determined by maize grain yield. The best objects were: PRP SOL with PRP EBV spraying and only PRP SOL, which increased the protein yield compared with the control respectively by 75.6 and 65.7 kg · $ha^{-1}$. Jakubus [11] and Marska and Wróbel [17] pointed out the important role of sulfur in creating the yield of protein. This element increases the activity of enzymes involved in the protein biosynthesis and through its presence with the nitrogen causes that N does not accumulate in the form of mineral ($N-NO_3$) but is incorporated into a series of protein process cycles. In studies of Filipek-Mazur et al. [8] the maize protein yield ranged from 465 to 1020 kg·$ha^{-1}$ and the highest yield of protein was obtained from the object fertilized with a dose of 160 kgN·$ha^{-1}$ with fertilizer containing 26% N in the form of nitrate and ammonium and 13% in the form of sulphate. Such a reaction of plants can be confirmed by the own results, as PRP EBV also includes sulfur, while PRP SOL unlocks the existing deposit of elements in the soil and increases their availability to plants [24]. Many studies have shown the superiority of the ionic form to elemental sulfur, which before incorporation to the plant, must be transformed in the soil by bacteria to sulfate form [5, 11]. PRP SOL effect on maize depends on the conditions in which it was applied. In previous, five-year study on maize (2007-2011), after the introduction of PRP SOL, total protein content in grain significantly decreased [27]. Such contradictory results may be due to water shortages in years of research and three months period of drought in spring. This is confirmed by studies of Noworolnik [22] which obtained a higher total protein content after the higher dose of nitrogen under short-lasting drought.

Maize starch is one of the main bypass products on the world market, needed in the food, chemical and paper industries [20]. Replacement of the traditional fertilization with PRP technology had a positive effect also on the yield of starch. On average over four years of research starch yield ranged from 7404.9 to 7986.4 kg·$ha^{-1}$. For objects with PRP SOL and PRP SOL + PRP EBV there were obtained respectively 581.5 and 533.4 kg $ha^{-1}$ more starch than in the control object. Also, in previous studies, the introduction of PRP SOL caused the increase of the concentration of starch in maize grain in comparison with the control by 3.19% points of dry matter [27]. The size of grain yield obtained in the present study depended on the weight of 1000 grains and fertilization did not diversify significantly the number of ears and the number of grains in the ear (Tab. 5). Maize plants grown with the use of PRP SOL and PRP SOL with PRP EBV produced kernels with increased mass, the differences relative to the control were respectively 7.6 and 8.8g. Larger grains after application of PRP SOL were also observed in earlier studies of Sulewska et al. [27]. Similarly, the application of PRP SOL in growing barley increased TKW by 0.3 g [24], whereas in the winter oilseed rape it was observed only such tendency [26]. In turn, the use of PRP SOL in winter wheat caused a significant decrease of TKW by an average of 0.9g [24].

In our study, it was noted the influence of fertilization on the grain moisture at harvest (Tab. 5). The use of PRP SOL and the additional spraying with PRP EBV in plants fertilized traditionally resulted in an increase in grain moisture, respectively by 0.7 and 0.9% points. In the present study, as in the previous with maize [27], occurred hectolitre grain weight after the application of fertilizers PRP which had character of tendency. On the other hand use of PRP SOL technology in oilseed rape [26] and barley [24] led to a statistically insignificant decrease in hectolitre weight compared with the control.

## 4. Conclusions

1. Replacing the traditional fertilization in corn by modern PRP technology, both the full version and PRP SOL alone, led to a significant increase in grain yield, as well as protein and starch yield.
2. Among all the analyzed characteristics the application of PRP SOL, and PRP SOL with PRP EBV spraying caused changes in leaf area index, plant height and weight of 1000 grains. The reaction of a maize plants, expressed by increase of the studied trait values was the proof of positive reaction to the modern technology of fertilization.
3. In the years of study, on the objects where PRP SOL and PRP SOL with PRP EBV spraying was used, it was noted significantly lower infection of plants by fungi of the genus *Fusarium* causing Fusarium stalk rot.

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