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The reaction of soybean *Glycine max* (L.) Merr. to the application of TS series stimulators

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Abstract. A field experiment to assess the response of soybean to the application of TS series stimulators was set up as complete blocks design with four replications. The investigated factor was growth stimulators (seed dressing – TS Osivo and foliar – TS Samson) produced by the Czech company BEIDEA s.r.o., compared to the control (without a stimulator). The reason behind the study was the lack of domestic reports regarding the impact of the use of TS series stimulators on the growth, development and morphological agronomic traits and yields of legume crops. The field trials were carried out in 2018–2019 at the Research Station operated by the Institute of Agroecology and Plant Production, Wrocław University of Environmental and Life Sciences, located in the district of Wrocław – Pawłowice (Dolnośląskie voivodeship). The tested crop was soybean, cultivar Abelina (maturity group 000 ++, breeder Saatbau Linz). Soybean seed dressing with TS Osivo stimulator caused an acceleration of germination and emergence phases from 2 to 4 days compared to the control treatment (water). The use of TS series stimulators in soybean cultivation contributed, in comparison to the control, to a significant increase (by 7.5%) in the plant height before harvest. Simultaneously, an increase in the height of first pod was observed, which reduces seed losses during harvest. Seed treatment with the TS Osivo stimulator increased seed yield by 5.8% compared to control treatment (without application). Spraying soybean with TS Samson stimulator increased the seed yield by 8.6%. In practice, in order to achieve an increase in soybean seed yield it is recommended to apply pre-sowing seed treatment with TS Osivo stimulator or foliar application of TS Samson.

Keywords: soybean, stimulator, TS, plant morphological features, yield, protein, fat

INTRODUCTION

Worldwide, soya ranks fourth after wheat, maize and rice in terms of cultivation area. In 2018, the USDA (United States Department of Agriculture) estimated the world's area under soybean at 125.8 million hectares. According to American reports (Haegele, Below, 2013), the high yield of soybean depends primarily on the course of pluvio-thermal conditions during the plant's growing season, the type of soil and its physico-chemical properties, and the cultivar chosen for cultivation. Global climate changes have an impact on weather conditions prevailing in Central Europe, including Poland. On the one hand, an increase in air temperature by about 3–4^{o}C, and on the other hand, only a slight increase in precipitation should be expected in the near future, which will extend the plant vegetation period in Poland (Kędziora, 2008; Nieróbca et al., 2013). This pattern of climate change is in line with the increased interest in the cultivation of soybeans for seeds by Polish agricultural producers, especially in the conditions of the Lower Silesian, Opole and Podkarpackie Voivodships. Considering that, in 2017, Poland imported 2.36 million tonnes of post-extraction soya meal (for almost PLN 4 billion) and about 385 000 tonnes of sunflower seeds, and the domestic sources of protein covered the feed needs only in about 30%, an extension of the non-genetically modified soya beans cultivation area in the country becomes a necessity. By ordinance of the Council of Ministers No. 222/2015 of 15 December 2015, established a multiannual programme (2016–2020) called "Increasing the use of domestic feed protein for the production of high quality animal products under conditions of sustainable development", which is to contribute to the increase of the country's so-called protein safety, also based on the extraction of seeds and soybean meal.

Therefore, Polish agricultural producers are constantly looking for new, alternative solutions to improve the growth, development and yielding of soya beans under different farming conditions. Some of them are already inclined to use bio-stimulators or growth and development stimulators in soya growing technologies to ensure the best possible conditions during the period of ontogenesis, inter alia, by reducing the adverse effects of various abiotic and biotic factors. A wide range of biostimulators/plant growth

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stimulators available in the world and in Poland may contain e.g. sea algae extracts, free amino acids, humic or phenolic compounds. When applied in crops of various species, they modify the course of photosynthesis, affect the transport of nutrients and water in the plant, increase the concentration of selected organic and mineral compounds, which in the end determines the size and quality of the obtained crops (Bulgari et al., 2015; Kocira et al., 2015a, b; Kocira et al., 2016; Przybysz et al., 2014; Tandon, Dubey, 2015).

The Czech growth stimulators TS is a group of products including 10 preparations with different compositions, dedicated to use in crop technologies of economically leading plants (sugar beet, peas, corn, poppy, wheat, barley, rapeseed, sunflower seeds, soybean). Most of them are based on the use of extracts from sea algae, free amino acids and humic acids and additionally selected macro and microelements in various proportions and concentrations (http://trisol.farm/index.html#produkty 2020). The main objectives for the application of the whole series of TS stimulators are to stimulate the germination and emergence of plants, increase the resistance to extreme weather conditions occurring during the vegetation period, increase the resistance to abiotic and biotic factors by strengthening the development of the underground and aboveground part of the plants and increase yielding while maintaining and/or improving the quality of the harvested yield (seeds, grains). So far, it has been shown (Špíšek et al., 2018) that the pre-sowing treatment of spring barley grain with the TS Osivo stimulator supports the development of the root system, which makes the plants less susceptible to periodic deficiencies in soil moisture during the growing season, stabilising the yield. A similar plant reaction to TS Osivo stimulator treatment of seeds was demonstrated in relation to winter oilseed rape, which not only increased the weight of the root system by 25.28%, but also increased the weight of the aboveground part by 34.71% in relation to control treatment (Koprna et al., 2017). As a result, the harvested rape seed yield was 6.86% higher than in the control treatment. An increase in winter rape seed yield of to 6.6%, as compared to the control treatment, due to spraying the plants with TS series stimulators was also recorded in Lower Silesia (Malarz et al., 2017). Furthermore, the preliminary research on the influence of TS series stimulators in spring barley and spring wheat cultivation under Polish agro-ecological conditions confirmed the beneficial effect of using TS Osivo in combination with other TS stimulators on the development and yield of both species (Kozak et al., 2017a, b).

The Lower Silesian and Opole Voivodships are the borderland between Poland and the Czech Republic. The proximity to the frontier, with soybean cultivation for seeds being developed on both sides of the border, leads to a wide access to various types of growth and development stimulators for agricultural producers. Currently, under the conditions of the Lower Silesia and Opole regions, there are no research results that would provide information on the influence of BEIDEA s.r.o. TS series stimulators on the development and yielding of cultivated soybean. Therefore, research in above mentioned area has been undertaken. The working hypothesis assumed that the application of diversified stimulators would have a positive effect on morphological features and yields of soybean cultivated for seeds.

MATERIALS AND METHODS

The research was carried out in 2018–2019 at the Research Station belonging to the Institute of Agroecology and Plant Production, Wrocław University of Environmental and Life Sciences, located in the Wrocław-Pawłowice district. The fields are situated at an altitude of approximately 147 m above sea level on the area of the Dobra river basin, the right-hand tributary of Widawa. Its eastern longitude is 17°02', northern latitude is 51°31'. A replicated field experiment was set up as a randomized complete blocks design with four replications. The surface area of a single experimental plot was 15.0 m^2 (1.5 m × 10.0 m). The experiment factor was the type of the applied TS series growth stimulator (seed dressing – TS Osivo, foliar – TS Samson), compared against the control treatment (without the application of the stymulator). The stimulator was manufactured by the Czech company BEIDEA s.r.o.

The TS Osivo stimulator is characterised by a minimum of 30% dry matter content, a minimum of 50% ash content, a minimum of 7% humic acids and their salts, a minimum of 10% amino acid content and a pH of 8–10. In addition, TS Osivo contains sea-algae extract, N, P, K, B, Mo, Fe in chelated form and Mg, Zn, Mn, Cu in sulphate form (http://www.trisol.farm/pripravky_profi/osivo.html 2020). The TS Samson stimulator contains: minimum 35% of dry matter, minimum 50% of ash ingredients, minimum 11% of amino acids, at pH 7–9. Simultaneously, TS Samson contains a low content of sea-algae extract and N, S, P, K as well as B and Mo (http://www.trisol.farm/pripravky_profi/samson.html 2020).

The experiment included 12 experimental fields each year (3 × 4 replications). The preceding crop was winter wheat, harvested in one stage with a combine-harvester on 8.08.2017 and 16.07.2018. Soil cultivation was carried out in the plough system. The winter plowing was done on 26.09.2017 and 26.10.2018 for the two study years, respectively. The soil was inverted in a square furrow slice that was left rough until next spring on. Each year, the spring field work began with levelling the experimental field with a cultivation unit and fertilisation with phosphorus and potassium in rates of 60 P_2O_5 and 120 K_2O kg ha^{-1}. Phosphorus was supplied to the soil as 40% granular superphosphate enriched, and potassium as 60% potassium salt. Starting nitrogen fertilization was applied at 30 kg ha^{-1}

N (pre-sowing plants) in the form of 34% ammonium nitrate. Soybean seeds were pre-plant treated (Table 1) with TS Osivo stimulator or sown untreated in the remaining experiment treatments (control, TS Samson application).

Table 1. Rates and dates of TS series stimulators application.

Stimulator	Rate	Growth phase	Date of application	
			2018	2019
Control	without application	-	-	-
TS Osivo	1,0 $dm^3 \cdot t^{-1}$	BBCH 00	26.04.	26.04.
TS Samson	0,80 $dm^3 \cdot ha^{-1}$	BBCH 13	30.05.	13.06.

The seeds of soybean cultivar Abelina (semi-early, early group 000++, bred by Saatbau Linz) were sown with the Tool Carrier 2700 plot drill in the third decade of April (26.04.2018, 26.04.2019) at a depth of 3–4 cm, at a row spacing of 15 cm, with a seeding density of 70 per 1 m^2. Soybean seed was characterized by the following parameters: weight of 1000 grains 178.5 g, germination capacity 95.0%, 100% purity in 2018 and weight of 1000 grains 173.0 g, germination capacity 90.0%, 100% purity in 2019. The herbicide Boxer 800 EC was applied pre-emergence (27.04.2018, 30.04.2019) at a dose of 4.0 dm^3 ha^{-1} in order to reduce the incidence of weeds. Graminicide Select Super 125 EC at a dose of 2.0 dm^3 ha^{-1} (23.05.) was applied against monocot weeds in 2018 and Super 125 EC at a dose of 2.5 dm^3 ha^{-1} (5.06.) in 2019. Secondary weed infestation was limited by the herbicide Corum 502.4 SL at the dose of 1.25 dm^3 ha^{-1} + DASH HC at the dose of 0.6 $dm^3 \cdot ha^{-1}$ (25.05.2018, 10.06.2019). No insecticide or fungicide treatments were used in the experiment. Spraying with the TS stimulator Samson in the BBCH 13 phase (30.05.2018, 13.06.2019) was performed with a tank mix of 0.80 dm^3 ha^{-1} of the stimulator in 300 dm^3 ha^{-1} of water, using a bicycle sprayer, at the working pressure of 0.30 MPa. Soybean plants in the control treatment were sprayed with plain water.

During their growth, soybean plants were observed for the dates of the beginning of the BBCH phases, and the number of days from sowing to the occurrence of a given development phase. After emergence and before harvest, the number of plants per 1 m^2 and the percentage of plants lost during vegetation were calculated. Before soybean harvest, 10 plants were randomly sampled from each experimental plot. From the sampled plants records were taken of the following features: plant height, height to 1st pod, number of 1st order branches, number of pods per plant, number and weight of seeds per plant and weight of seeds per pod. The plants were harvested on 3.09.2018 and 20.09.2019 with the Seedmaster Universal Hydrostatic field harvester. After the harvest, the seed yield from each plot was determined and then converted to yield per 1 hectare and adjusted to a fixed moisture content of 13%. The qualitative analyses of the harvested plant material were performed at the Institute of Agroecology and Plant Production, Wrocław University of Environmental and Life Sciences by the following methods (Krełowska-Kułas, 1993): dry matter – drying method at 105±2ºC during 5 h, total nitrogen content (total protein) – Kjeldahl method; in seeds total nitrogen was determined and converted to total protein using the coefficient of 5.71, crude fat (ether extract) – using the defatted residues method in Soxhlet apparatus. The size of the aggregate sample (weight) of plant material, separately for each of the chemical analyses, was 1 gram. The chemical analyses were carried out in two repetitions each time. Total protein and crude soya bean fat yields were calculated as a function of the obtained seed yields and percentage of individual components.

The results were tested under analysis of variance (AWA/ANOVA), with the significance level at $\alpha = 0.05$. The Shapiro-Wilk test was not performed. The significance of differences between the mean values was assessed using Tukey's HSD test (Elandt, 1964).

Soil and weather conditions

In the years 2018–2019, the field experiment was performed on a luvisol classified in the soil order of Alfisols (Kabała et al., 2019), developed from a sandy loam on underlying clay, classified as the good wheat soil suitability complex and belonging to III b quality class. In 2018, the soil reaction was slightly acidic, with the following content of available nutrients: phosphorus – very high, potassium – medium, magnesium – high, while in 2019, the soil reaction was slightly acidic with the medium content of available phosphorus and potassium and high content of magnesium (Table 2).

In 2018, during the spring tillage and sowing of soya (2nd and 3rd decade of April), air temperatures were above the averages from 1981–2010 (Table 3), leading to rapid heating of the topsoil. As a result, the germination of seeds and plant emergence were quick and even. The persistence of high air temperatures in May 2018 (average 17.1°C) with simultaneous precipitation close to long-term levels brought about a shortening of the plant vegetative development and the transition to the early flowering phase already in the first decade of June.

Further hot weather periods (June, July, August), especially with a lack of precipitation in August 2018 (20.3 mm total) shortened the flowering, pod formation and seed ripening phases. During the 2018 growing season, soybean reached full seed maturity already at the end of August.

Weather conditions in spring 2019 were less favourable for soybean germination and emergence (Table 3). The scarcity of precipitation in the first and second decade of April caused the sowing of soybean seeds to be carried out

Table 2. Selected soil chemical properties before setting up the experiment.

Replication	pH 1 M KCl	P	K	Mg
		mg·kg⁻¹ gleby mg·kg⁻¹ soil		
2018				
I	6.5	165	151	72
II	6.5	126	133	77
III	6.5	122	122	77
IV	6.5	142	132	82
2019				
I	5.6	57	160	90
II	5.7	55	166	90
III	5.7	59	157	84
IV	6.0	63	158	88

Table 3. Meteorological conditions during the soybean growing season in 2018–2019.

Decade	Month						
	Mar	Apr	May	Jun	Jul	Aug	Sep
	air temperature [°C]						
	2018						
I	-1.9	10.5	15.9	20.6	18.8	24.2	18.2
II	2.0	15.2	15.4	19.4	18.6	20.9	17.6
III	3.5	15.3	19.7	16.4	22.5	18.3	11.6
Monthly average	1.3	13.7	17.1	18.8	20.1	21.1	15.8
	2019						
I	6.7	10.5	9.5	20.9	17.7	20.2	16.3
II	6.1	8.3	11.6	23.0	17.6	19.0	13.0
III	7.2	13.5	14.8	22.3	22.4	21.4	13.9
Monthly average	6.8	10.8	12.1	22.1	19.3	20.3	14.4
Average for years 1981–2010	3.8	8.3	14.1	16.9	18.7	17.9	13.6
	precipitation [mm]						
	2018						
I	7.0	3.2	12.9	6.2	24.8	2.7	10.2
II	10.0	7.0	32.9	7.6	49.2	3.5	11.5
III	10.6	8.8	8.5	22.8	5.1	14.1	16.7
Monthly sum	27.6	19.0	54.3	36.6	79.1	20.3	38.4
	2019						
I	10.3	0.0	9.4	1.3	3.2	13.6	34.4
II	8.4	5.2	20.6	4.2	2.8	38.6	3.9
III	3.8	19.0	46.8	21.5	44.1	7.6	3.7
Monthly sum	22.5	24.2	76.8	27.0	50.1	59.8	42.0
Average for years 1981–2010	31.7	30.5	51.3	59.5	78.9	61.7	45.3

in dry soil, which at low air temperatures in the first and second decade of May resulted in prolonged germination of the seeds. The improvement of humidity conditions in the second and third decade of May caused strong vegetative development of the plants, which, being accompanied by very high air temperatures in June (average 22.1°C), further postponed the start of soybean flowering to as late as the third decade of June. Generative development of soybean in 2019 was very intensive, due to air temperatures far exceeding the long-term averages (1981–2010) in July and August, with a good water supply of plants, thanks to rainfall in August (59.8 mm). The weather conditions in 2019 were more favourable to pod formation and seed ripening that resulted in obtaining high seed yields, compared to the 2018 growing season.

RESULTS

The growth and development of soybean, including the beginning of individual developmental phases, in the years of the study were primarily dependent on the progress of thermal and humidity conditions in individual vegetation seasons, followed by the application of the TS Osivo growth stimulator (Table 3, 4). In 2018, the beginning of soybean plant emergence was already 9 days after sowing, in the case of using the TS Osivo stimulator. In untreated soya bean seeds, the emergence phase started 2 days later. In less favourable weather conditions for germination and emergence (year 2019), seed treatment with TS Osivo stimulator vs. the application of untreated seeds accelerated the appearance of the first plants by 4 days to (Table 4). The differentiation in the rate of appearance of subsequent soybean growth phases, as influenced by the TS Osivo application, continued until phase 3 of leaf (BBCH 13) in both years of the study. In comparison with plants grown from untreated seeds it was 1–2 days. The rate of growth and development of soybean from the budding phase (BBCH 51) was evened out, regardless of the application of TS Osivo, however, the differences caused by various patterns of weather conditions in individual years of the study became apparent. TS Samson stimulator did not affect soybean development stages.

In 2018, the soybean flowering period (BBCH 61-69) lasted only 13 days, while in the 2019 as many as 30 days, which depended on thermal and humidity conditions. Simultaneously, in 2018, the period from the end of flowering (BBCH 69) to the full seed maturity phase (BBCH 89) covered 71 days of plant growth, whereas in 2019 it was 46 days (Table 4). Differentiation in the length of the soybean growing period depending on the course of weather conditions in the years of the study also became evident. In 2019, the period from sowing to full maturity was 9 days longer than in 2018.

The number of soybean plants per 1 m^2 after emergence and before harvest did not significantly depend on the application of TS series stimulators (Table 5). The density of

Table 4. Starting dates of soya growth stages in 2018–2019.

Development of plants	Scale BBCH	2018		2019	
		starting dates of stages	number of days from sowing date	starting dates of stages	number of days from sowing date
sowing	00	26.04.	–	26.04.	–
Emergence[1]	10	5.05.	9	10.05.	14
Emergence[2]	10	7.05.	11	14.05.	18
1 leaf[1]	11	12.05.	16	17.05.	21
1 leaf[2]	11	14.05.	18	21.05.	25
2 leaf[1]	12	21.05.	25	29.05.	33
2 leaf[2]	12	22.05.	26	31.05.	35
3 leaf[1]	13	29.05.	33	11.06.	46
3 leaf[2]	13	30.05.	34	13.06.	48
Budding	51	5.06.	40	21.06.	56
Beginning of flowering	61	8.06.	43	25.06.	60
Flowering	65	15.06.	50	2.07.	67
End of flowering	69	21.06.	56	25.07.	90
Green maturity	79	1.08.	97	8.08.	104
Yellow maturity	80	23.08.	119	30.08.	126
Full maturity	89	31.08.	127	9.09.	136
Harvest	99	3.09.	130	20.09.	147

[1] with application of TS Osivo; [2] without application of TS Osivo

plants per unit area after the plant emergence was similar to the values expected at designing the experiment and became evened out in all research treatments. Plant losses during vegetation were slight and also independent of the application of stimulators. Between the years under comparison, a significantly lower plant density after emergence and before harvest was recorded in the growing season of 2019, while at the same time the losses of soybean plants during growth were higher (6.2%).

Morphological features of soybean plants were significantly determined by the type of stimulator applied in comparison with the control treatment and by the variation of weather conditions in individual years of the study (Table 6). The application of TS series stimulators in soybean cultivation contributed, as compared to the control, to a significant increase (by 7.5%) in the height of plants before harvest. At the same time, their positive impact on the increase in the height of the first pod was noted. The above information is of great importance for agricultural practice due to the reduction of seed losses by pruning the lower pods during harvesting. In this respect, the treatment of soybean seeds with the TS Osivo stimulator proved to be particularly beneficial, since it caused the position of the first pods on soybean plants to be significantly the highest (13.3 cm). The number of branches of the first order was significantly lowest in the control, while, it remained unaffected by type of stimulator. A similar relationship was observed with respect to the number of pods on the plant, which was the lowest in the control treatment (27.2). The application of stimulator TS Osivo increased the number of pods on soybean plants by 11.4% in relation to the control

Table 5. Number of soybean plants per 1m^2 and plant losses during growth (%) (averaged across years).

Specification	Number of plants after emergence per 1 m^2	Number of plants before harvest per 1 m^2	Losses of plants during vegetation [%]
Control	63	60	5.0
TS Osivo	62	60	4.4
TS Samson	62	59	4.7
HSD	r.n.	r.n.	r.n.
2018	64	62	3.2
2019	61	57	6.2
HSD	2	3	2.0

control – without application of stimulators
r.n. – difference not significant (α = 0.05)

Table 6. Morphological features of soya plants before harvest (means for factors).

Specification	Height of plants [cm]	Height to the 1st pod [cm]	Number of 1st branches	Number of pods per plant
Control	80	11.6	2.9	27.2
TS Osivo	86	13.3	3.7	30.3
TS Samson	86	12.3	3.7	29.8
HSD	2	0.5	0.2	1.3
2018	76	8.8	2.8	27.7
2019	92	15.9	4.1	30.5
HSD	2	0.4	0.2	1.0

control – without application of stimulators
r.n. – difference not significant (α = 0.05)

treatment. However, no significant difference in the number of pods on the plant under the influence of different TS series stimulators was observed.

In terms of weather conditions, the year 2019 favouredhigher values of all morphological features of soybean plants assessed before harvest, as compared to those in 2018 (Table 6). This was particularly evident for plant height, height of the first branch and number of pods on the plant. This testifies to how highly variable were the biometric features of soybean plants over the study seasons, which has a direct bearing on managing the crop e.g. on how and at what speed combine harvesting should be conducted.

The elements shaping the yield of soybean seeds assessed in the experiment were significantly determined by the effect produced by the application of TS series stimulators (Table 7). Both pre-sowing seed dressing with the stimulator TS Osivo and foliar spraying with the TS Samson at the leaf development stage contributed to an increase in the number and weight of seeds from a single plant, the weight of seeds in the pod and the weight of 1000 seeds, as compared to the control treatment. However, no significant variation was found for how the stimulators influenced the above soybean plant characteristics.

The humidity and thermal conditions in 2019 vs. 2018, were more advantageous for the generative development of soybean, which was reflected in the formation of a larger number of seeds, with simultaneously higher weight per plant and per pod as well as higher weight of 1000 seeds (Table 7). After the application of the stimulators TS Osivo or TS Samson, the weight of 1000 soy beans increased by 2.9% in relation to the control treatment. Soybean plants, due to a longer flowering period in 2019 (Table 4), developed a higher number of pods, which under propitious weather conditions were gradually filled up with well-sized seeds.

The treatment of TS series stimulators contributed to a significant increase in the yield of soybean seeds (Table 8). The pre-sowing seed treatment with the stimulator Osivo TS statistically significantly increased the seed yield, as compared to control treatment, by 5.8% on average. Moreover, it was found that foliar spraying with stimulator TS Samson during soybean leafing phase generated 8.6% yield increase, as compared to the control treatment. In turn, the concentration of total protein and crude fat in seeds was not significantly modified by application of the above stimulators. Total protein and crude fat yields achieved from 1 ha were the outcome of the obtained seed yields and percentage of individual components. Foliar application of TS Samson generated significantly the highest total seed-accumulated protein yield (1.234 t ha^{-1}). Similar crude fat yields from 1 ha were obtained regardless of the type of stimulator used and were significantly higher in comparison with the control treatment (Table 8).

The soybean seed yields obtained, both in experimental and field production, are strictly dependent on the distribution of air temperatures and precipitation during the various stages of plant development. Therefore, in the analysed research years, high seed yields close to 4.5 t ha^{-1} were obtained from soybean grown in 2019. Moreover, in 2019, a significantly higher total protein content in soybean seeds was recorded compared to that in 2018, with simultaneous lack of statistical differences for to crude fat content. The yields of total protein and crude fat from 1 ha were closely related to the size of the harvested seed yield. The total protein content was more affected by year of experiment than crude fat content, and this relation was reflected also in these components yields (Table 8).

Table 7. Elements shaping the yield of soybeans (means for factors).

Specification	Number of seeds per plant	Weight of seeds per plant [g]	Weight of seeds per pod [mg]	Weight of 1000 seeds [g]
Control	48.9	8.5	299	171
TS Osivo	60.1	10.6	346	176
TS Samson	61.8	10.9	352	176
HSD	2.5	0.5	16	1
2018	52.7	9.5	321	173
2019	61.1	10.5	344	175
HSD	2.1	0.4	13	1

control – without application of stimulators

Table. 8. Yields of seeds, total protein and crude fat, and chemical composition of soya seeds (means for factors).

Specification	Seed yield [t ha^{-1}]	Content of total protein [%]	Content of crude fat [%]	Total protein yield [t ha^{-1}]	Crude fat yield [t ha^{-1}]
Control	3.62	34.3	23.1	1.092	0.731
TS Osivo	3.83	34.7	22.7	1.168	0.757
TS Samson	3.93	35.5	21.9	1.234	0.749
HSD	0.05	r.n.	r.n.	0.015	0.010
2018	3.13	32.1	22.3	0.875	0.607
2019	4.46	37.5	22.8	1.454	0.884
HSD	0.04	1.7	r.n.	0.013	0.008

control – without application of stimulators
r.n. – difference not significant ($\alpha = 0.05$)

DISCUSSION

The previous studies (Bobrecka-Jamro, Pizło, 1996; Jasińska et al., 1996; Kołodziej, Pisulewska, 2000; Michałek, Borowski 2006) have shown that the development and yields of soybean in different regions of Poland were most strongly influenced by weather conditions during the growing period. Additionally, Bury and Nawracała (2004) pointed out that the prevailing factor shaping the growth and development of soybean in warmer years was precipitation deficit. The system of pluvio-thermal conditions also determines the chemical composition of seeds and post-harvest soybean residues, while the application of stimulators does not always significantly affect the content of individual organic and mineral components (Kozak et al., 2008). In this study, higher values of plant morphological characteristics, yield-forming elements and seed yields were recorded in 2019, which was characterised by a longer growing season. Among the assessed features, the number of pods per plant and the number and weight of seeds per plant had the greatest influence on the level of obtained soybean seed yields. In this respect, earlier reports by Lorenc-Kozik and Pisulewska (2003) have been confirmed, indicating that the yield of soya beans is shaped mainly by the number of pods formed on the plant and the weight of seeds from the plant.

Since during their growth plants are constantly exposed to various abiotic and biotic factors influencing their yield, agricultural producers try to limit their negative impact by, among other things, applying biostimulators/stimulators at various developmental stages. Grzyś (2012) concluded that the effectiveness of biostimulators is significantly dependent on the method of their application and the development phase of plants. In this study, seed dressing with the stimulator TS Osivo caused acceleration of germination and plant emergence, and provided a faster rate of growth up to the budding phase, compared to control (without dressing). In relation to other leguminous species, Klimek-Kopyra et al. (2019) proved a significant influence of biostimulators application on the initial development of winter pea seedlings.

Current studies (Kocira et al., 2018; Kozak et al., 2008; Prado et al., 2016) indicate a significant impact of biostimulators containing sea-algae extracts, humic acids, amino acids, phenols on yields and quality characteristics of soybean. In this study, the yield of soybean seeds increased under the influence of TS Osivo and TS Samson stimulators by 5.8 and 8.6%, respectively, in relation to the control treatment. Rathore et al. (2009) demonstrated that spraying with sea-algae extracts could increase soya bean yields by up to 50%, depending on the concentration used and the course of weather conditions during the growing season. In contrast, Oliveira et al. (2019) report that the use of certain biostimulators (Stimulate®) can significantly reduce soybean yields, as a result of a reduction in the number of developed pods on the plant by up to 37%. A positive effect of the application of TS series stimulators has also been reported in the cultivation of wheat, barley and rape (Frydrych, 2018; Kozak et al., 2017 a, b; Painter et al., 2017; Špíšek et al., 2018), which justifies the advisability of their practical use in the cultivation technologies of various crops.

CONCLUSIONS

1. The application of TS Osivo and TS Samson stimulators favourably influences the morphological features of soybean, e.g. by increasing the height of the first pod on the plant, which facilitates harvesting and reduces the seed losses.
2. The number and weight of seeds from a plant and the weight of 1000 seeds, that are the elements determining the level of soybean seed yields, are significantly dependent on the use of TS series stimulators.
3. In practice, in order to achieve an increase in soybean seed yield it is recommended to apply pre-sowing seed treatment with stimulator TS Osivo or foliar application of TS Samson.

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