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Effect of Pre-Sowing Seed Treatment on the Yield and Quality of Soybeans in the Subtaiga of Western Siberia

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***Abstract*— The effect of pre-sowing seed treatment with fertilizers on the yield and quality of soybean grain in the subtaiga zone of Western Siberia was investigated. Tests were performed in the subtaiga zone of the Omsk Region in 2015-2017, on gray forest soils. Results showed that the duration of the soybean growing season was influenced by weather conditions and seed treatment with rhizotofin and combined seed treatment with rhizotorfin and "TurMax legumes" complex fertilizer. When treating seeds with them, it was prolonged for 3 days in 2016 and for 5 days in 2017 what is associated with the better supply of nutrients. On average, the difference in the duration of this period over 3 years was insignificant and amounted to 2 days. On average, over 3 years of research the number of nodules in variants with rhizotorfin treatment was 5.6 pcs/plant, and in the variant with combined fertilizer treatment it was the highest – 9.2 pcs/plant. The number of beans, seeds in the bean and the weight of a thousand seeds were also the largest in the variant with the combined treatment of seeds with fertilizers. On average, over the years of research, the highest yield of 1.41t/ha was provided in the variant with combined treatment with rhizotorfin and TurMax. The lowest protein content through all years was observed in control variant and averaged 29.6%. In the variant with rhizotorfin treatment, it increased and averaged 32.6%. In the variant with combined seed treatment with rhizotorfin and TurMax, it was the largest – 34.7%. The combination of yield and protein content contributed to the fact that on average for 3 years the highest protein yield of 491.8 kg/ha was provided by the variant of co-treatment of soybean seeds before sowing. Thus, production enterprises should be recommended to perform pre-sowing seed treatment with rhizotorfin and complex fertilizer containing macro- and microelements.**

Keywords—seeds, fertilizers, microelements, soybean, yield, protein.

I. INTRODUCTION

The problem of increasing protein production is today one of the most important and urgent in fodder and crop production in Russia, and also in Western Siberia. High-protein crops are of high importance in solving this problem, and one of these crops is soybean [1, 2]. Soybean is one of the leading agricultural crops in the world; it is the basis of the economy of many countries [3]. In connection with the expansion of soybean sowing areas in different regions of Russia, soybean varieties, its biological features, the possibility of its cultivating in different soil and climatic zones, and the corresponding agricultural techniques are being developed and widely investigated. So, during a 50-year breeding work using hybridization method with multiple single plant selection, a unique Siberian gene pool of fast-ripening soybeans was created in the Siberian Research Institute of Agriculture. Long-term and comprehensive study of soybean in the southern forest-steppe of Western Siberia, as well as new varieties adapted to these conditions along with well-developed set of agrotechnical measures guarantee success in growing this crop in the forest-steppe zone of the Omsk Region [4].

Decades of experience in the study of soybean cultivation techniques in the subtaiga zone of Western Siberia have shown that a sum of active temperatures is sufficient for the growth, development and formation of a soybean crop of 1.60-1.72 (up to 2.74-2.81) t/ha. Soybean productivity depended on the average daily air temperature during "start of flowering – ripening" period. Optimal conditions for grain filling, protein accumulation and formation of seeds with high sowing qualities were obtained at early sowing dates (until May 20) [5].

The most important feature of soybean is its ability to fix atmospheric nitrogen in order to satisfy its own nitrogen needs in symbiosis with nodule bacteria. In most Siberian soils there are no natural bacteria required for soybean, so it is necessary to treat seeds with bacterial preparations, otherwise soybean will lack nitrogen and will not be able to form a full grain crop [6]. Soybean, like other legumes, is sensitive to the lack of microelements and responds well to the application of micronutrients. It was established that with a deficiency of manganese, boron and molybdenum, no seeds are formed in beans [7]. Gray forest soils of the subtaiga zone of the Omsk Region have insufficient amount of several microelements [8]. Therefore, the topical issue is to study the effect of inoculation of soybean seeds and their processing with complex fertilizer containing microelements on the gray forest soils of Western Siberia. In the southern forest-steppe of Western Siberia, the relationship of soybean grain yield with elements of its structure, nodule formation and grain quality was studied by E.N. Ozyakova [9].

Goal of research: to study the effect of pre-sowing seed treatment with "Rhizotorfin for soybeans" bacterial fertilizer and with "TurMax legumes" complex mineral fertilizer on the yield and quality of soybean grain in the subtaiga of Western Siberia.

II. Conditions and methods

The experiments were performed in the subtaiga zone of the Omsk Region in 2015-2017. The climate of this region is typically continental with severe cold winters, warm, and in the south of the region even hot but short summers, with short spring and autumn, short frost-free periods, sharp fluctuations in temperature from month to month, from one day to another and even during the day.

Northern parts of the Omsk Region, including Tarsky District, are characterized by lower air temperatures than in other parts of the region. Average duration of the period with a temperature above 10°C which corresponds to the period of active plant vegetation is 105-119 days. Period with higher average daily air temperatures (15°C and higher) which are suitable for growing more heat-loving crops, ranges from 55-65 days. Frost-free period lasts an average of 100-115 days with significant variance from the average from 70 to 150 days in several years. The sum of average daily temperatures for the period with a temperature above 10ºC is 1,650-1,850ºC. According to long-term average data, annual amount of precipitation is 360-430 mm, from 300 to 360 mm for the warm period (April – October) and from 220 to 250 mm for the period with a stable average daily temperature above 10ºC (period of active vegetation). Hydrothermal index is 1.3-1.5 what indicates sufficient moisture supply during active vegetation period [10].

Vegetation period in 2015 was warm and humid, average daily air temperature was 1.1°C higher, and precipitation was 63.2 mm higher in comparison with the long-term average data. In 2016, it was hot, with precipitations 51.2 mm less than normal. Average daily air temperature in 2017 was higher than the long-term average one by 0.9°C, it was the most humid year – precipitation was 117.2 mm more than the long-term average value. Weather conditions of the years of research had effect on the growth, development and yield of soybeans.

Experiments were performed on gray forest heavy loamy medium acidic soil with a low content of humus, phosphorus and potassium, in 4-fold repetition, with a randomized allocation of plots.

The object of the study was the effect of soybean seed pre-sowing treatment with the preparations made by OOO PlantaPlus biotechnological enterprise on its yield and quality. Liquid fertilizers were used: "Rhizotorfin for soybeans" and "TurMax legumes" [11]. TurMax legumes is a complex mineral fertilizer containing a complete set of macro - and micronutrients required for the full growth and development of plants. It includes N, P, K, S, Mg, Fe, Ca, Zn, B, Mn, Mo, Cl, Co, Ni, I, Cr, Se.

The following seed pre-sowing treatment variants were studied:

1) Seeds with no treatment (control);

2) Seed treatment with Rhizotorfin at the rate of: 2 L/ton;

3) Seed treatment with Rhizotorfin at the rate of: 2 L/ton and with "TurMax legumes" complex fertilizer at the rate of: 0.25 L/ton

For this study, we have taken Sibiryachka soybean variety regionalized in the Omsk Region and obtained at the Siberian Research Institute of Agriculture (Omsk).

Agricultural technology during experiment: The predecessor was cereals; immediately after their harvesting plowing was carried out to the depth of arable horizon. In the spring, when the soil reached physical ripeness, harrowing was carried out, and immediately before sowing, cultivation was performed to the depth of 5-6 cm. At the day of sowing, seeds were processed according to the recommendations for the use of studied fertilizers. Sowing was carried out in the second decade of May, in common row way, to the depth of 5 cm. Seeding rate was 1.0 mln germinating seeds per hectare. Crop tending began with rolling and included weed control. Harvesting was performed by direct combining at the stage of full ripeness.

In the course of experiment, the following calculations and observations were carried out according to the methodology of the State Testing [12]:

1) Phenological observations. Emergence and ripening were registered. The onset of the stage was established with its onset in 10% of plants; the date of full phase was noted when 75% of plants reached it.

2) Nodules were counted during seed filling.

3) Analysis of crop structure.

4) Allocated grain yield accounting. The data were brought to 100% purity and standard humidity.

5) Protein content in soybean grain was defined at "Tarskaya" Agrochemical Station according to GOST 10846-91.

6) Mathematical processing by analysis-of-variance method according to B.A. Dospekhov.

The experiments were performed in areas where soybeans did not grow before.

III. Results

Results of these studies showed that the weather conditions during the years of study and the studied variants had an impact on the duration of soybean growing season. So, in 2015, the soybean growing season was the longest in all variants, since the year was the coolest with average daily air temperature of 15.9°C and large amount of precipitation – 307.9 mm (Table 1). In all cases, plants did not reach their full ripeness due to frost damage, since on September 17 minimal temperature in the grass was -8.8°C, and on the soil surface -5.0°C. Plants at this time were at the stage of yellow ripeness.

In 2016, with a higher average daily air temperature and the least amount of precipitation, the duration of growing season was the shortest and amounted to 95 days in the control and 98 days in the variants with treatment. In 2017, the duration of this period also amounted to 95 days in the variant with no treatment and lasted up to 100 days in the variants with treatment. This is due to better nitrogen nutrition caused by the formation and working of nodules. In 2017, this period in variants with treatment was longer than in 2016 what was associated with cooling (decrease in air temperature after September 4 below 10°C).

TABLE I. CONDITIONS AND DURATION OF SOYBEAN VEGETATION PERIOD

Variant	Year	Vegetation period, days	Average daily temperature, °C	Sum of active temperatures, °C	Sum of precipitation, mm
1.No treatment (control)	2015	106	15.9	1579.8	307.9
	2016	95	18.3	1705.6	210.3
	2017	95	17.4	1625.6	329.9
	average	99			
2.Seed treatment with rhizotorfin	2015	106	15.9	1579.8	307.9
	2016	98	18.2	1705.6	210.3
	2017	100	17.0	1638.5	355.4
	average	101			
3.Seed treatment with rhizotorfin and TurMax	2015	106	15.9	1579.8	307.9
	2016	98	18.2	1705.6	210.3
	2017	100	17.0	1638.5	355.4
	average	101			

On average, the difference in period duration over 3 years was insignificant and amounted to 2 days.

Thus, weather conditions during the years of research and seed treatment with fertilizers influenced the duration of soybean growing season. In the case of seed treatment, it was prolonged for 3 days in 2016 and for 5 days in 2017 what is associated with a better supply of nutrients.

Seed treatment with rhizotorfin and combined treatment with rhizotorfin and TurMax complex fertilizer contributed to the formation of nodules on the root system. That is, the studied variants and weather conditions during the years of research had an effect on the formation of nodules. In the variant with no seed treatment, there was found one nodule at single plants. When treating seeds with rhizotorfin, the number of nodules increased significantly, and in the variant with the addition of complex fertilizer, it was even more. The largest number of nodules – 6.9 and 10.8 in the 2nd and 3rd variants, respectively – was observed in the warmest 2016 (Table 2). On average, over 3 years of research, the number of nodules in the variants with rhizotorfin treatment was 5.6 pcs/plant; and in the variant with combined fertilizer treatment it was the highest – 9.2 pcs/plant.

TABLE II. NUMBER OF NODULES PER 1 PLANT DURING FILLING PERIOD, PCS.

Variant	2015	2016	2017	Average
1. No treatment (control)	0.1	0.1	0.2	0.1
2. Seed treatment with rhizotorfin	4.3	6.9	5.6	5.6
3. Seed treatment with rhizotorfin and TurMax	7.9	10.8	7.8	9.2

Agrometeorological factors, seed treatment and the number of formed nodules have an impact on plant productivity and yield in future. Just as the number of nodules, the largest number of beans per 1 plant was observed in warm 2016, it was slightly less in 2017, and even less in the coolest 2015 in all variants. In the variant with seed treatment with rhizotorfin, the number of beans through all years increased more than 2 times and averaged 6.85 pcs/plant over the years of research in comparison with to 3.19 pcs in the variant with no treatment. In the variant with the combined treatment with two types of fertilizers, the number of beans was larger compared to the control and to seed treatment with rhizotofin and amounted to 7.22 pcs.

TABLE III. NUMBER OF BEANS PER 1 PLANT, PCS.

Variant	2015	2016	2017	Average
1. No treatment (control)	2.87	3.73	2.97	3.19
2. Seed treatment with rhizotorfin	6.64	7.33	6.58	6.85
3. Seed treatment with rhizotorfin and TurMax	6.94	7.69	7.03	7.22

The number of seeds in the bean depended on the treatment variant and was the largest over 3 years –1.84 pcs. in the variant with combined seed treatment (Table 4). It was the smallest – 1.58 pcs – in the variant with no treatment. Moreover, in first two variants, the largest number of beans was in the warmest 2016, and in the third version – in warm 2017. The smallest number of seeds in a bean in the first and second variants was in cool 2015, and in the third variant – in 2016.

TABLE IV. NUMBER OF SEEDS IN BEAN, PCS.

Variant	2015	2016	2017	Average
1.No treatment (control)	1.54	1.62	1.59	1.58
2. Seed treatment with rhizotorfin	1.67	1.76	1.73	1.72
3. Seed treatment with rhizotorfin and TurMax	1.84	1.80	1.88	1.84

The size of seeds was also influenced by the conditions during the years of study and fertilizers. So, in all variants, the largest seeds were in the warmest 2016, the smallest – in the coolest 2015. Also, during all years, the weight of 1,000 seeds increased significantly at the treatment of seeds with rhizotorfin; and the largest weight was during the treatment of seeds with rhizotorfin and "TurMax legumes" complex fertilizer. On average, over the years of research, the weight of 1,000 seeds in the 2nd and 3rd variants, respectively, amounted to 166.5 and 175.0 g (Table 5). In control variant, the seeds were the smallest with weight of 1,000 grains of 129.4 g.

TABLE V. WEIGHT OF 1,000 SEEDS, G

Variant	2015	2016	2017	Average
1. No treatment (control)	126.4	133.5	128.4	129.4
2. Seed treatment with rhizotorfin	160.7	176.1	162.8	166.5
3. Seed treatment with rhizotorfin and TurMax	171.8	178.4	174.9	175.0

All this factors have an impact on yield. It was the highest in 2016, the lowest – in 2015. During all years, the yield was significantly higher at seed treatment with rhizotofin and at combined processing in comparison with the control. In cool 2015, the variant with co-treatment with fertilizers also had an advantage over treatment with rhizotorfin. The yield was 1.32 t/ha (Table 6). In warmer 2016 and 2017, there was no significant advantage between the second and the third variants. On average, over the years of research, the highest yield – 1.41 t/ha – was provided in the variant with combined treatment with rhizotorfin and TurMax. The lowest yield – 0.4 t/ha – was in the control variant.

TABLE VI. YIELD,T/HA

Variant	2015	2016	2017	Average
1. No treatment (control)	0.33	0.49	0.37	0.4
2. Seed treatment with rhizotorfin	1.07	1.38	1.13	1.19
3. Seed treatment with rhizotorfin and TurMax	1.32	1.50	1.40	1.41
HCP $_{0,5}$	0.155	0.306	0.431	

Protein content in grain also depended on weather conditions and variant of pre-sowing seed treatment. So, the highest protein content was formed in the warmest conditions of 2016 that are characterized by less precipitation; the lowest – in the cool conditions of the growing season 2015. The lowest protein content during all years was in the control variant and averaged 29.6% (Table 7). In the variant with rhizotorfin treatment, it increased and averaged 32.6%. In the variant with combined seed treatment with rhizotorfin and TurMax fertilizer, it was the largest – 34.7%.

TABLE VII. PROTEIN CONTENT, %

Variant	2015	2016	2017	Average
1. No treatment (control)	20.4	36.2	32.2	29.6
2. Seed treatment with rhizotorfin	24.8	39.7	33.4	32.6
3. Seed treatment with rhizotorfin and TurMax	26.1	40.4	37.5	34.7

As a result, weather conditions of the year and the studied variants also had an effect on protein yield per hectare (Table 8).

TABLE VIII. PROTEIN YIELD, KG/HA

Variant	2015	2016	2017	Average
1. No treatment (control)	67.3	177.4	225.4	156.7
2. Seed treatment with rhizotorfin	265.4	547.9	377.4	396.9
3. Seed treatment with rhizotorfin and TurMax	344.5	606.0	525.0	491.8

Combination of yield and protein content contributed to the fact that on average for 3 years the highest protein collection – 491.8 kg/ha – was provided in the variant with pre-sowing co-treatment of seeds with two fertilizers.

IV. CONCLUSIONS AND RECOMMENDATIONS

Thus, the results of three years of research on the effect of pre-sowing seed treatment with fertilizers revealed the following:

1) Weather conditions of the years of research and seed treatment with fertilizers had an effect on the duration of soybean growing season. In the case of seed treatment, it was prolonged for 3 days in 2016 and for 5 days in 2017 what is associated with a better supply of nutrients. On average, the difference in period duration over 3 years was insignificant and amounted to 2 days.

2) The number of nodules in control variant was 0.1 pcs/plant, in the variant with rhizotorfin treatment it was 5.6 pcs/plant, and in the variant with combined fertilizer treatment it was the highest – 9.2 pcs/plant. Maximal number of nodules – 6.9 and 10.8 in the 2nd and 3rd variants, respectively – was observed in the warmest 2016.

3) The larger number of beans and of seeds in bean formed during combined processing with fertilizers. In the same variant, there were the largest seeds with the weight of 1,000 grains of 175.0 g.

4) The highest grain yield – 1.41 t/ha – was obtained in the variant of treatment with rhizotorfin and "TurMax legumes" complex fertilizer

5) The highest protein content (34.7%) and yield (491.8 kg/ha) were provided during combined seed treatment with fertilizers.

Production enterprises should be recommended to perform mandatory pre-sowing seed treatment with rhizotorfin and complex fertilizer containing microelements.

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