The influence of stressful weather conditions on the formation of soybean productivity when using growth-regulating drugs in the conditions of the Moscow region

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Abstract. Modern soybean varieties of the northern ecotype are grown in the Central Region of the Russian Federation, which is important for solving the problem of vegetable protein deficiency and food security. Stressful weather conditions at certain stages of the growing season (drought, lack of heat) can have a strong effect on the yield formation and the maturity of soybeans. The article presents the results of a field experiment on the effect of stressful weather conditions of the 2019 season and the use of biologically active substances on the growth, development and formation of soybean elements of productivity in Moscow region.

1 Introduction

High temperature (Heat stress) and drought (Water deficit stress) at different stages of the production process cause complex and irreversible changes in the growth, development, and formation of productivity elements in grain legumes, including soybeans [2, 7, 8, 9]. Such stressful conditions are happening more and more often due to climate change. They are the cause of instability and variability of soybean yields even when growing this crop in the most favorable climatic regions of the USA, Brazil, and Argentina – the main suppliers of soybeans to the world market [6, 11].

Modern soybean varieties of the northern ecotype are grown in the Central Non-Chernozem region of the Russian Federation, which is important for solving the problem of plant protein deficiency and food security in Russia. Stressful weather conditions at certain stages of the growing season (drought, lack of heat) can have a strong impact on soybean yield and ripening [1, 2].

2 Materials and Methods

The research was carried out at the RSAU-MAA Field Experimental Station in 2019. The RSAU-MAA Field Experimental and Breeding Station is located in typical conditions for the

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Central Region of Russia. The soil of the experimental site is sod-podzolic, medium loamy. The arable horizon contains 28.8 mg P_2O_5 and 10.1 mg K_2O per 100 g of soil. In the field experiment of the Department of Crop Production and Meadow Ecosystems, where the effect of biologically active substances (BAS) on the formation of the soybean crop was studied, in 2019, stressful weather conditions were fully manifested. The purpose of this study is to determine and analyze data on the effect of stressful weather conditions on plants in the control without treatment and in variants with BAS under stressful conditions on the soybean production process in the Moscow region.

The research object is a soy variety Kasatka. The variety was created at the Ryazan Agricultural Experimental Station, which was transformed into the Research, Design, and Technological Institute of the Agro-industrial Complex - Ryazan RDTI AIC. According to the description of the variety authors, the Kaasatka is an ultra-ripe soybean variety of the northern ecotype. The variety is included in the State Register of Breeding Achievements and is approved for production in the Central region [3].

The scheme of the experiment included control without treatment and treatment by spraying with BAS solutions (Zircon, Epin - extra, Ecofus, Siliplant), in the phase of the beginning of flowering according to the method developed by the authors of the preparations (*ANO "NEST M"*: Epin-extra 40 ml/ha, Zircon 20 ml /ha). For the preparations Siliplant and Ecofus, the dose is 1 and 3 l/ha, respectively [4]. The flow rate of the working fluid for all BAS is 400 l/ha. The size of the experimental plot is 9 m^2, in 4 repetitions. Placement of variants by the method of rendomized blocks. Agrotechnics of cultivation - adopted for the zone. The soy forecrop is root crops. Soybean sowing was carried out on May 6, 2019 in moist soil with an Amazone D9-30 seeder with a row spacing width of 45 cm, a drilling depth of 3-4 cm. The seeding rate was increased to form the same density of 50 plants/m^2 in the field of seedlings in all variants . The BAS treatment of plants was carried out with a manual sprayer in accordance with the experiment scheme. During the period from germination to the closing of the rows, manual weeding was carried out as necessary. In the studies, phenological observations were carried out, the density of plant standing, plant growth in height, elements of the crop structure, and seed yield were determined according to generally accepted methods.

3 Results

Germination density and plant survival. After sowing with a seed drill with an overestimated seeding rate and the appearance of thickened seedlings, the plant density was formed in all variants at the rate of 50 plants/m^2. Despite the stressful conditions, the plant survival rate was high (94-98%). This is confirmed by the authors' studies, which indicate a significant role of plant adaptation to drought [5,7]. There was a tendency of a positive BAS effect on the survival of plants.

Meteorological conditions of the growing season of 2019 are presented according to the results of observations of the V.A.Mikhelson Meteorological Observatory of the RSAU – MAA named after K.A. Timiryazev, they significantly deviated from the long-term average values (Fig.1).

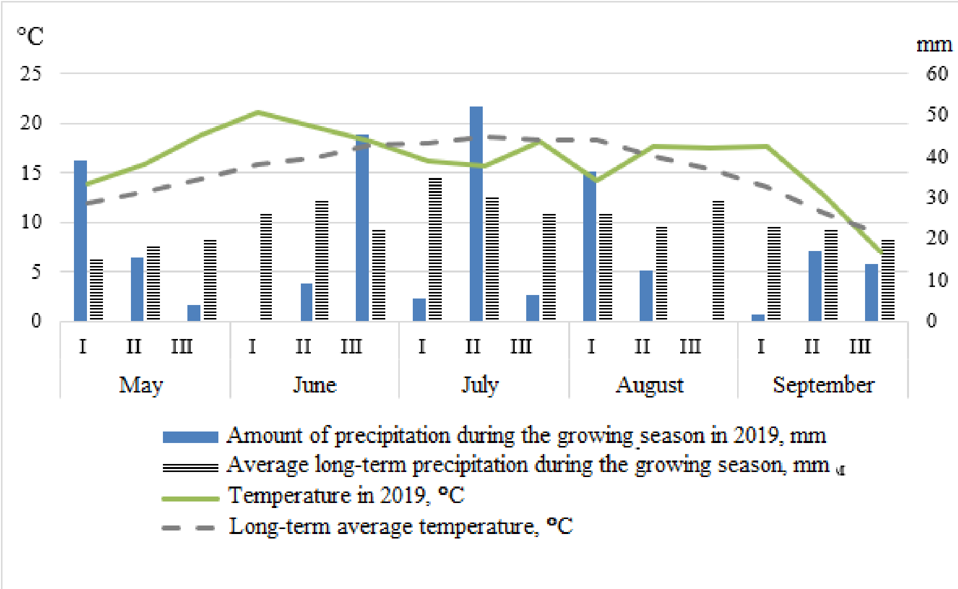

Fig. 1. Meteorological conditions.

During the period of vegetative growth, as well as in the subsequent period, the weather was hot and dry. From germination to the beginning of flowering (May 13), precipitation practically did not fall, and the average daily air temperature is 3-5 C degrees exceeded the average long-term. During the critical period of flowering and fruit formation (14.06 - 30.06.) precipitation was only in the 3rd decade of June, the temperature was above normal. The plants experienced both heat stress and moisture deficiency stress (drought). Under these stressful conditions, plant growth and photosynthesis of crops were suppressed, few beans were formed on the plants. In August, during the period of seed filling and ripening, there was also warm and dry weather, which accelerated the development of plants. The duration of vegetation from sowing to full ripening was 106 days in all variants.

The determination in the dynamics of plant growth in height showed that in conditions of severe drought, all plants were very stunted (Table 1).

Table 1. Plant growth in height, cm and plant weight, g/m2.

Options	Plant growth	Raw mass	Dry mass
Control	26.8	717	251
Siliplant	31.0	839	341
Zircon	33.7	1050	352
Epin-extra	35.8	974	365
Ecofus	34.5	869	263
Average by options	32.4	890	315
LSD_{05}	2.32	138	43,6
Sigma	3.6	128	135
V%	11.1	14,4	124

The plant height in the control was below 30 cm. BAS had a significant impact on the plant growth in height. In the variants with BAS, the plants were 6-9 cm higher than in the control. There is also a tendency to increase the attachment height of the lower bean.

Under the stressful conditions of the 2019 season, the leaf area and photosynthetic potential (PP) of plants were very low (Table 2).

Table 2. Leaf area, photosynthetic potential (PP), and net photosynthetic productivity (NPP).

Option	Leaf area, thousand m^2/ha	PP, thousand m^2 days/ha	NPP, g/m^2 per day
Control	8.38	405	6.20
Siliplant	8.13	483	6.21
Zircon	10.9	539	6.53
Epin-extra	10.6	527	6.93
Ecofus	11.4	489	5.38
Average by options	9.88	478	6.59
LSD_{05}	1.55	65.6	0.78
Sigma	1.52	58.5	0.93
V%	15.3	12.2	14.0

The net productivity of photosynthesis (NPP) turned out to be a fairly stable indicator. Differences in options, including control, were within the limits of the LSD. The role of biostimulants as regulators of plant growth and photosynthesis is indicated in the studies of a number of authors [9, 10]. In our studies, the leaf area and photosynthetic potential were significantly higher than the control: by 20-30%, depending on the variant.

In terms of the number of beans and seeds per m^2, the Zircon and Epin-extra variants significantly exceeded the control. In the Siliplant and Ecofus variants, the differences were unreliable compared to the control (Table 3).

Table 3. Components of the crop structure and seed yield.

Options	Beans / m^2	Seeds / m^2	Weight of 1000 seeds, g	Seed yield, g/m^2
Control	504	1059	104	110
Siliplant	599	1211	121	146
Zircon	613	1346	124	166
Epin-extra	659	1408	134	186
Ecofus	560	1234	120	148
Average by options	587	1252	120	151
LSD_{05}	89	201	11.3	33.8
Sigma	58.0	134	10.5	28.4
V%	9.9	10.7	8.75	18.7

Nevertheless, by the weight of seeds, plants of all variants with BAS significantly exceeded the control. Studies have shown that plants in variants with BAS had undoubted advantages during the seed filling period before the control without treatment. Obviously, this is due to the best conditions for plant photosynthesis in previous periods. Indeed, the weight of 1000 seeds in the variants with BAS was 20 – 28% higher than in the control.

In the stressful conditions of 2019, there is an increase in the action of random factors, which manifested in significant deviations of seed productivity by repetition from the average for the option and a high value of LSD. It is shown that the variants with BAS differ significantly and fairly from the control in terms of seed productivity. The best indicators are in the Epin-extra variant. Due to the low yield in one of the repetitions, Zircon was inferior to Epin-extra. Siliplant and Ecofus were 20% less effective compared to Epin-extra.

4 Conclusion

One of the important and promising directions of managing the production process of agricultural crops against the background of changing climatic and weather conditions is the use of plant growth stimulants. They help plants to reach their potential, make better use of environmental resources and withstand adverse weather conditions [1, 4, 9, 10].

In the experiment (2019) at the Field Experimental Station of the RSAU-MAA named after K.A. Timiryazev the effect of stressful weather conditions on growth processes, photosynthetic activity of plants, the formation of productivity elements and soybean yield was determined. The positive effect of biologically active substances Epin-extra, Zircon, Siliplant, and Ecofus on the indicators of crop formation and seed productivity of soybean plants of the northern Kasatka ecotype in drought conditions has been established.

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