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Influence of inoculation and morphoregulator on growth of plants of soya bean in conditions of Forest-steppe

The purpose. To determine dependences of influence of inoculation and morphoregulator on processes of growth, development and productivity of seeds of soya bean. **Methods.** System analysis, field, laboratory, settlement-relative, mathematical-and-statistical. **Results.** Under the influence of morphoregulator Chlormequatchloride on the background of inoculation there was an inhibition of linear growth of plants of soya bean due to decrease of length of internode and increase of diameter of caulis. It promoted magnification of its strength and enhanced stability of plants against lodging, created technological advantages at harvesting. The maximum productivity of seeds of grades KiVin, Kniazhna, Monada is gained on plots where they used inoculation of seeds with bacterial preparation Optimize and further processing of sowings of soya bean by solution of Chlormequatchloride in budding stage. **Conclusions.** The technique of growing soya bean on the basis of complex application of inoculation of seeds and Chlormequatchloride is developed. Orders of application of morphoregulator in sowings of soya bean with the purpose to increase yield of seeds are justified. The expediency of application of synthetic growth inhibitors of plants with antigibberellin gear of action in state-of-theart techniques of growing soya bean is proved.

Key words: soya bean, Optimize, Chlormequatchloride, height of plants, length of internodes, diameter of caulis, productivity.

Introduction. In recent years, Ukraine has been experiencing a growing interest in soybean production. Soybean has become a market-oriented and leading crop in Ukraine’s crop production. In 2016, the area under it amounted to 1,846 million hectares. However, over the past 5 years, soybean yields have ranged from 1.62 to 2.17 t/ha, which is 1.8 times less than that of the leading soybean-growing countries such as the USA, Argentina, and Brazil. It should be noted that soybean varieties have genetic yield potential of 6.5-7.5 t/ha, which is 2-3 times higher than that achieved in the production conditions of Ukraine [1]. This indicates that the processes

of plant growth and development and conditions for implementation of soybean seed yield potential have not been fully investigated. In addition, a dynamic increase in cropping areas together with a decreased attention to biological features and cultivation technology leads to a decrease in crop yields. Therefore, the development of new and improvement of current soybean cultivation technologies based on seed inoculation and application of morphoregulators is an important scientific problem that requires a detailed study and scientific substantiation taking into account biology of varieties and climate fluctuation.

Analysis of recent researches and publications. One of the main criteria for researching technologies of crop cultivation is analysis of the processes of growth and development of plants in agrocenosis [2]. Plant height is an important factor in forming a vertical structure of the soybean field agrocenosis, which determines its air and light regime. Formation of generative organs and the level of productivity largely depend on the height of soybean plants [3].

It is known that a hormonal system plays a key role in the plant growth regulation, and a physiological effect depends on both concentration of certain phytohormones and their ratio. Ontogenetic changes in the ratio of gibberellins, cytokinins and auxins significantly affect the growth processes and features of the histogenesis of vegetative and generative organs of plants [4, 5].

The mechanism of retardants' effect on the processes of plant growth is based on the ability to inhibit cell division in the subapical meristem of the sprout blocking synthesis or activity of already synthesized gibberellins. Influencing apical and marginal meristems, retardants cause a decrease in the linear size of plants [6, 7].

The use of retardants is based on the properties of redistribution of nutrient flow towards increasing not to the top of the growth point, but to the root. Thus, downstream sap flows improve mineral nutrition of the lower buds and the root [8]. At the same time, apical growth of plants does not stop. As a result, truncated and thickened stems are formed, plastic materials are redistributed between the stem and reproductive organs, structural elements that determine the level of seed yield are formed more intensively [9].

One of the factors that significantly affects the growth processes of soybean plants is inoculation. It has been noted that pre-sowing treatment with bacterial preparations based on nitrogen-fixing bacteria had a stimulating effect and resulted in the increase in plant height [10]

Materials and methods. The study was conducted during 2013-2015 at the Institute of Feeds and Agriculture of Podillia of NAAS on gray forest mid-loamy soils with content of humus 2.66% (according to Tiurin), easily hydrolyzed nitrogen - 43.5 mg/kg of soil (according to Cornfield), mobile phosphorus - 214 mg/kg of soil and exchangeable potassium - 104 mg/kg of soil (according to Chyrykov). Reaction of soil solution was pH 5.1-5.8. Hydrolytic acidity was 1.86-2.16 mg equivalents/100 g of soil. The amount of absorbed bases was 18.8-30.1 mg-equivalents/100 g of soil.

It was supposed to study the effect and interaction of three factors: A – variety: KyVin (early), Kniazhna (middle), Monada (middle) (originator – the Institute of Feeds and Agriculture of Podillia of NAAS); B – seed inoculation: without treatment, seed treatment with Optimize, 2.8 l/t; C – concentration of morphoregulator (chlormequat-chloride, 750): 0.5%, 0.75%, 1.0%. Ratio of factors – 3x2x4. Four-time replication of the experiment. The area of the registered plot was 25 m^2, the total area of the site was 54 m^2. The predecessor was a cereal grass. The system of fertilization included application of phosphoric and potash fertilizers (superphosphate and potassium salt) based on $P_{60}K_{60}$ under basic soil tillage and nitrogen fertilizers in the form of ammonium nitrate (N_{30}) under pre-sowing cultivation. The seeds was treated with Maxim XL 035 FS (1 l/t of seed) 14 days before sowing. Inoculation was carried out one day before sowing. In the period of vegetation (the phase of budding), there was used a retardant at various concentrations (standard working solution of 200 l/ha) on variants of the experiment according to the scheme.

Research results. Based on the conducted researches it was established that the height of soybean plants increased from the phase of emergence to physiological maturity due to the growth of plant biomass and depended on the genotype properties of the variety. In particular, it was noted that the highest plant height in the phase of physiological maturity was observed in Kniazhna variety – 81.7-92.3 cm, in KyVin

variety it ranged within 79.8-89.53 cm and in Monada variety – 75.4-84.3 cm (Table 1).

Table 1. The dynamics of soybean plant height depending on inoculation and retardant concentration, cm (on average for 2013-2015).

Varieties	Concentration of chlormequat-chloride, %	Without inoculation	Inoculation Optimize, 2,8 l/t
KyVin	without treatment (к)	85,8 ±13,4	89,5 ±13,3
	0,5	83,5 ±13,3	88,3 ±12,3
	0,75	80,5 ±12,8	85,9 ±11,5
	1	79,8 ±12,5	83,1 ±12,6
Kniazhna	without treatment (к)	88,2 ±10,6	92,3 ±10,5
	0,5	84,5 ±10,5	88,1 ±11,8
	0,75	83,3 ±10,1	85,4 ±10,8
	1	81,9 ±9,80	84,7 ±10,7
Monada	without treatment (к)	79,8 ±11,4	84,3 ±10,2
	0,5	77,9 ±11,0	79,8 ±11,2
	0,75	76,0 ±10,5	78,8 ±10,6
	1	75,4 ±10,7	77,1 ±10,4

It was established that the height of soybean plants did not change significantly before the budding phase, but since the phase of full flowering the height difference between the variants greatly increased and was significant.

Thus, seed inoculation with bacterial preparation Optimize based on the strain *B. japonicum* had a stimulating effect and caused the increase in the soybean plant height regardless of the effect and interaction of other organized factors.

In particular, on the sites where inoculation was applied, plant height in the phase of full maturity in KyVin variety was 89.5 cm, Kniazhna variety - 92.3 cm and Monad variety - 84.3 cm, which was 3.7 cm, 4.1 cm and 4.5 cm more, respectively, than that in the control variant.

Treatment of soybean crops in the budding phase with chlormequat-chloride in different concentrations led to slower plant growth due to its antigibberellin action, which manifests as the ability to block synthesis or retention of this hormone by plant

cells [11]. Morphogenetic consequences of the retardant effect are manifested in the reduction of longitudinal cell size and internode length, resulting in a decrease in the total height of plants. Stem height can be reduced by 13.9-35.0%, and sometimes up to 60% [12, 13].

Thus, application of 0.5% solution of chlormequat-chloride in soybean crops of KyVin variety reduced the plant height indices by 2.27-1.2 cm in comparison with the variants without treatment with the retardant; the difference in height when treated with 0.75% and 1% chlormequat-chloride solutions was 5.5-3.63 cm and 6.04-6.4 cm, respectively.

Similar dependence was also noted in Kniazhna and Monada varieties. The lowest plant height was observed when soybean seed was treated with 1% retardant solution, and it was 81.86-84.66 cm and 75.37-77.11 cm, respectively, which was 6.36-7.61 cm and 4.43-7.22 cm lower in comparison with the control variant.

Correlation and regression analysis of the indicators of height and concentration of the morphoregulator revealed a strong negative relation as it caused a decrease in the height of soybean plants. A correlation coefficient for the KyVin variety was r = - 0.718, Kniazhna - r = - 0.852, Monada - r = - 0.825.

The influence of the synthetic growth regulator and seed inoculation on the structural and functional organization of soybean stems, which indicate significant changes in the processes of morphogenesis, was established. It was found that the change in the internode length and stem diameter occurred from the fifth internode. Stem diameter in the 1-4 internodes was formed depending on the varietal characteristics.

Changes in the stem size in experimental plants occurred due to the increase in the bark size. The influence of chlormequat-chloride manifested in the increased width of the sclerenchymal ring, growth of the main parenchyma, increase in the number of vascular-fibrous beams and surrounding elements of the mechanical tissue [14].

When chlormequat-chloride was introduced in the budding phase and further development of plants, the increase in the stem diameter was observed. Thus,

application of 0.5% solution of chlormequat-chloride against a background of inoculation and without it resulted in the increase in the stem diameter in the fifth internode by 3.1 - 6.3%, respectively, in Kniazhna variety by 4.1-4.3% and in Monada variety the diameter increased by 8.6-8.3%, compared with the plants of the control variant.

Maximum diameter of the stem in the fifth internode in KyVin variety increased when applying 1.0% chlormequat-chloride solution and seed inoculation with Optimize and it equaled 5.51 mm and exceeded a control one by 20.9%.

A similar dependence was observed in Kniazhna and Monada varieties, however, 0.75% concentration of the retardant solution appeared to be more effective. The stem diameter in Kniazhna variety was 5.61 mm, which was 29.1% more than in the control variant. This indicator was the highest in Monada variety (6.04 mm), gain to control was 25.3%. At the same time, it was found that the variants where inoculation was conducted had somewhat higher indicators than in the variants without it. Such specificity of shoots differentiation due to the growth regulator effect contributes to the enhancement of the mechanical strength of the stem, which, in its turn, provides technological advantages when harvesting.

As a result of the conducted correlation and regression analysis, a strong positive correlation was established between the retardant concentration and stem thickness. A correlation coefficient for KyVin variety was r = 0.791, Kniazhna r = 0.748, Monada r = 0.727. A significant and moderate correlation was obtained between the stem diameter and inoculation, namely, for KyVin variety r = 0.548, Kniazhna r = 0.322, Monada r = 0.374.

Consequently, the best development of mechanical tissues was observed under the effect of retardants against a background of inoculation, which, in its turn, contributed to the increase in the stem diameter.

In addition, one of the objectives of the research was to determine the effect of the retardant and inoculation on the anatomical index of soybean plant stems, i.e. internode length.

It was found that the factors investigated had a significant effect on the

internode length. This indicator averaged 6.18 cm in the control variant, and when 0.75% and 1% retardant solution was applied it reduced to 4.52 cm. A varietal respond was noted when applying these elements of the technology.

Kniazhna variety is characterized by a higher plant height among the studied varieties and has a long stem and elongated internode; therefore, it is susceptible to lodging. When applying a retardant, there was observed an internode decrease, which prevented plant lodging. Maximum length of the fifth internode reduced when applying 0.75% chlormequat-chloride and was 4.85 and 5.45 cm, that was 28% and 30% less compared with the control (6.85-7.8 cm) (Figure 1).

KyVin and Monada varieties formed the shortest internodes when applying 1% and 0.75% solution of chlormequat-chloride and amounted to 4.3-5 cm and 4.15-4.45 cm, that was 26-20% and 28-30 % less in comparison with the control variant (5.8-6.25 cm and 5.80-6.35 cm). Consequently, it was found that the indices of the internode length of the soybean stem depended on the concentration of chlormequat-chloride solution.

Correlation and regression analysis shows a strong negative relationship between internode length of soybean plants and concentration of the retardant solution as well as a significant and moderate relationship between internode length and seed inoculation. A correlation coefficient between internode length and the retardant concentration was $r = -0.813$ for KyVin variety, $r = -0.693$ for Kniazhna variety, $r = -0.787$ for Monada variety. A correlation coefficient between the internode length and seed inoculation was $r = 0.548$ for KyVin variety, $r = 0.389$ for Kniazhna variety, and $r = 0.383$ for Monada variety.

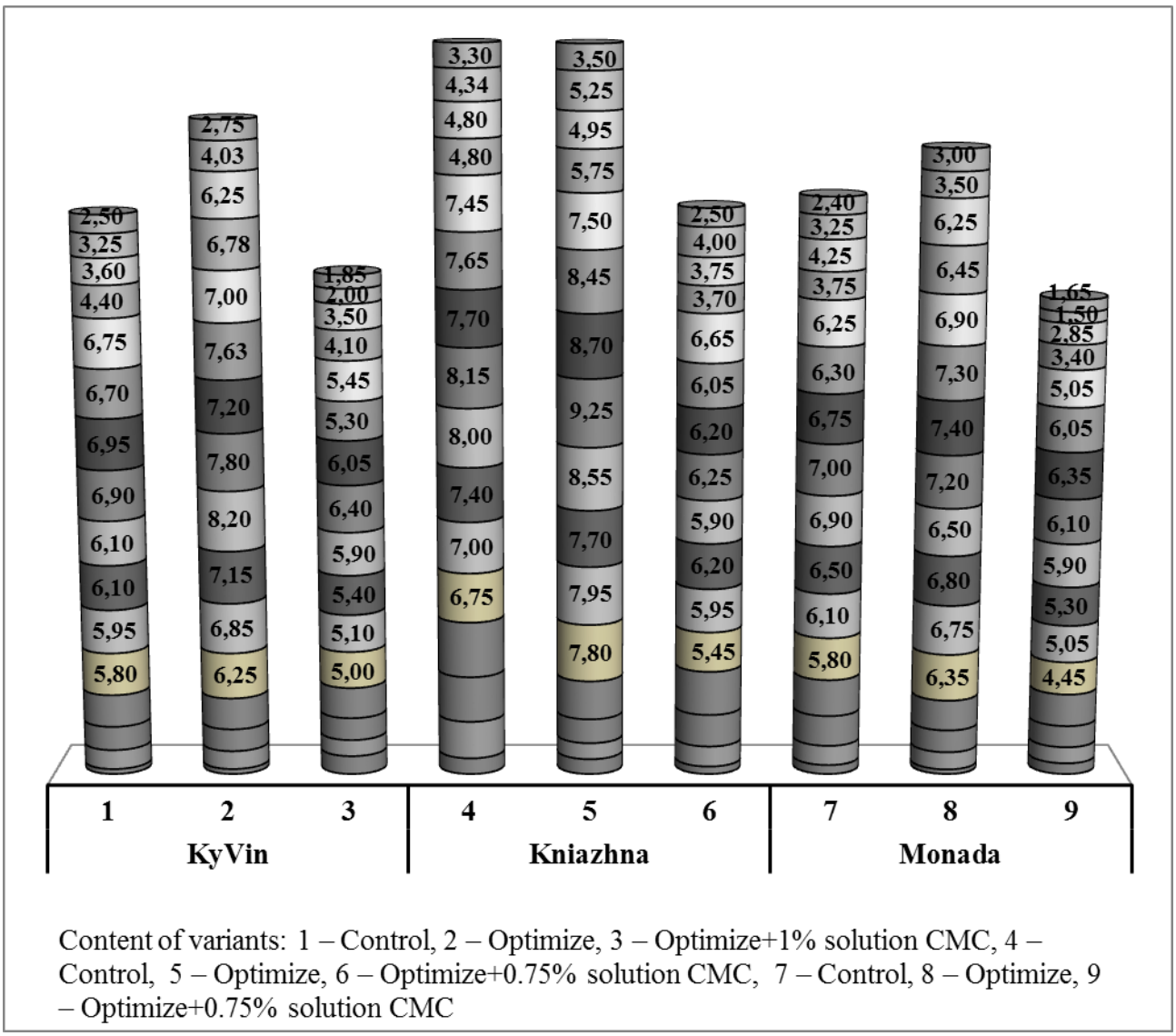

Fig. 1. Soybean internode length under the effect of inoculation and chlormequat-chloride, cm (on average for 2013-2015)

Regulation of the processes of growth and development of plants with the help of physiologically active substances provides a directed influence on some stages of ontogenesis in order to mobilize genetic capacities of the plant organism and, ultimately, to increase yields of agricultural crops, including soybean.

Thus, yields of soybean varieties during 2013-2015 ranged within 1.45-2.39 t/ha. Maximum yield of 2.39 t/ha was observed in Monada variety, somewhat lower yield of 2.13 t/ha in KyVin variety and 2,14 t/ha in Kniazhna variety obtained due to seed treatment with bacterial preparation Optimize and crop spraying with chlormequat-chloride in the budding phase, which was 40, 47 and 38% more, respectively, as

compared to control (without bacterization and treatment of crops with a retardant) (Table 2).

It should be noted that the varieties responded differently to the concentration of chlormequat- chloride. Thus, 1% concentration was the most effective for KyVin variety, while 0.75% concentration appeared to be the most effective for Kniazhna and Monada varieties. Seed inoculation of these varieties provided yield increase by 16, 17, and 15%, respectively.

2. Effect of morphoregulator and inoculation on soybean seed yield, t/ha (on average for 2013-2015)

Varieties	Concentration of chlormequat-chloride, %	Without inoculation	Inoculation Optimize, 2,8 l/t
KyVin	without treatment (к)	1,45	1,64
	0,5	1,57	1,82
	0,75	1,69	1,96
	1	1,80	2,13
Kniazhna	without treatment (к)	1,55	1,77
	0,5	1,72	2,04
	0,75	1,79	2,14
	1	1,69	1,99
Monada	without treatment (к)	1,72	1,92
	0,5	1,90	2,17
	0,75	2,06	2,39
	1	2,04	2,35

Note: factor A – variety, factor B – inoculation, factor C – retardant concentration.
$HIP_{0,05}$, t/ha A – 0,0156; B – 0,0127; C – 0,0180; ABC – 0,0441

Conclusions. Thus, the treatment of soybean plants with chloromequat-chloride in the budding phase caused changes in the growth processes, namely the retardant inhibited the linear growth of plants due to the decrease in the internode length and increase in the stem diameter. Under the effect of the retardant, the diameter of stems in KyVin, Kniazhna and Monada varieties increased by 26-41%, which improved resistance of soybean plants to lodging and provided technological

advantages when harvesting. Seed treatment with the bacterial preparation Optimize had a stimulating effect.

Maximum seed yield in Monada variety of 2.39 t/ha, KyVin of 2.13 t/ha and Kniazhna of 2.14 t/ha was obtained under seed treatment with bacterial preparation Optimize and spraying of crops with chlormequatchloride in the budding phase, which was 40, 47 and 38% more, respectively, compared with control (without crop bacterization and treatment of crops with the retardant).

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