UDC 631.581.5:631524.84:633.34
DOI: 10.32636/agroscience.2025-(4)-4-5

THE INFLUENCE OF GROWTH-STIMULATING SUBSTANCES ON THE GROWTH AND PRODUCTIVITY OF SOYBEANS

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In modern agriculture, the interest is growing in biofertilizers and biologically active substances, to be more precise in plant growth stimulants, as environmentally safe alternatives to traditional agrochemicals. Soybean, being a leading food and feed crop, plays a key role in global food security. This study analyzes the effectiveness of various growth stimulants on soybean productivity, focusing on field trials.

Studying the impact of growth stimulants on soybean yield, product quality, and adaptability to stress conditions is extremely relevant, especially in the context of climate change in Ukraine. The review of scientific data published in 2021-2025 includes more than 30 studies from Ukraine, Brazil, Iraq, and Southeast Asia. The biostimulants analyzed include seaweed extracts, amino acids, vitamins (folic acid, nicotinamide, thiamine), microbial inoculants (BioMag, Rhizogumin-Plus) and synthetic phytohormones. The results show that these substances activate physiological and biochemical adaptation mechanisms, increase water use efficiency, strengthen antioxidant systems and improve nutrient uptake. In particular, the combined use of growth stimulants and inoculants demonstrated a significant increase in leaf surface area, plant height, number of beans, seed weight and total yield.

The use of biostimulants also improves grain quality, increasing protein and lysine content. The integration of these biological substances into soybean cultivation technology is an effective and sustainable approach that contributes to increased yield, improved product quality and reduced dependence on traditional agrochemicals, in line with the principles of sustainable agriculture.

Keywords: soybean, biostimulants, plant growth stimulators, yield, stress resistance, sustainable agriculture.

Introduction

In recent years, the global agricultural sector has been actively transitioning to more sustainable and environmentally friendly practices. One of the key aspects of this transformation is the growing interest in biofertilizers and biostimulants, especially plant growth promoters, which are seen as a viable alternative to traditional agrochemicals.

Soybean (*Glycine max L.*) is an important food and feed crop that plays a crucial role in ensuring global food security and agricultural sustainability. Improving its productivity, stress resistance and grain quality through innovative and environmentally friendly means is a priority, especially in the context of climate change in Ukraine and other vulnerable regions.

The physiological and biochemical mechanisms by which growth promoters affect soybean development have attracted considerable attention. These compounds, which include algae extracts, amino acids, vitamins and microbial inoculants, can activate adaptive responses to abiotic stresses such as drought, heat and soil salinity. They also contribute to improving nutrient uptake, water use efficiency and oxidative stress management in plants.

Scientific studies have shown that such substances can significantly improve vegetative growth, reproductive performance and ultimately yield stability under different environmental conditions. Given the growing body of evidence on the benefits of biostimulants in soybean cultivation, it is critical to evaluate their effectiveness in specific agro-ecological zones and production systems. This study aims to analyze the effects of different growth stimulants on soybean productivity, focusing on field trials.

By evaluating physiological responses, yield parameters and grain quality under different treatments, the study aims to provide practical recommendations for the integration of biostimulants into sustainable soybean production technologies.

Materials and methods

This review article is based on a comprehensive analysis of the scientific literature published between 2021 and 2025 investigating the effects of plant growth promoters on soybean (*Glycine max L.*) under different agroecological and climatic conditions. Sources were selected using scientific databases such as Scopus, Web of Science, PubMed and Google Scholar.

Key search terms included "soybean", "growth promoters", "biostimulants", "plant growth regulators", "abiotic stress" and "yield response". Preference was given to peer-reviewed scientific articles, field trial reports and publications with statistically validated results.

In total, more than 30 scientific studies were analyzed, including international and regional studies,

including from Ukraine, Brazil, Iraq and Southeast Asia. These studies covered different categories of biostimulants, such as seaweed extracts (e.g. *Ecklonia maxima, Padina minor*), amino acids, vitamins (e.g. folic acid, nicotinamide, thiamine), microbial inoculants (e.g. BioMag, Rhizogumin-Plus), and synthetic plant hormones (e.g. gibberellic acid, mepiquat chloride, chlormequat chloride). Additionally, studies investigating synergistic applications, e.g. biostimulants combined with inoculation, were carefully reviewed to evaluate integrated approaches to enhance soybean resistance and productivity.

The analysis focused on identifying common physiological parameters (e.g., plant height, leaf area, number of pods, seed weight), biochemical parameters (e.g., protein content, antioxidant activity, nitrogen metabolism), and agronomic outcomes (e.g., yield, drought tolerance, nutrient use efficiency).

A comparative assessment of treatment efficacy under both optimal and stressed conditions was conducted to summarize current knowledge and identify consistent trends. The methodological rigor of each study, including experimental design, repeatability, and statistical processing, was also considered to ensure the validity of the conclusions drawn in this review.

Results and discussion

In modern agricultural production, the growing demand for biofertilizers is accompanied by increased interest in biologically active substances, especially plant growth stimulants. They are increasingly considered as an environmentally friendly alternative to traditional agrochemicals. Soybean, as the cornerstone of global agriculture, occupies a critically important place among the leading food and feed crops.

Therefore, the study of the impact of growth stimulants on soybean yield, product quality and its ability to adapt to stress conditions is very relevant, especially given the challenges posed by climate change in Ukraine. This section aims to review the existing scientific data on the physiological mechanisms by which various growth stimulants affect soybean plants, their impact on key agronomic indicators and promising ways of their integration into modern crop production technologies.

To increase soybean resistance to abiotic factors — such as drought, heat stress and soil salinity — the strategic use of natural biostimulants is considered very promising. This category includes substances such as seaweed extracts, amino acids and microbial inoculants (Shelest et al., 2023). These beneficial substances act by activating key physiological and biochemical adaptation processes in the plant, leading to optimized water use efficiency, enhanced antioxidant systems and improved absorption of essential mineral nutrients (Sankhala et al., 2024).

For example, a study conducted by Shepilova et al. (2025) in the Northern Steppe of Ukraine during 2022–2024 provided compelling evidence that the use of stimulants such as Arise, Atonik Plus, Gumifield and Mars EL in combination with seed inoculation with BioMag Soya significantly increased the growth and yield of the soybean variety Azimuth under the current drought conditions.

The most impressive results were achieved with the combined use of Mars EL and BioMag, which demonstrated an increase in leaf area, plant height, number of pods and seed weight per plant. This synergistic application resulted in a significant increase in yield of 4.2 t/ha (20.6%) compared to the control group.

A study by Al-Fahdawi and Mustafa (2023) in Baghdad further illustrated these benefits, showing that foliar spraying with folic acid (2 g/L) significantly increased protein content, antioxidant activity, free radical inhibition levels and flavonoid concentration in soybean. Glutathione (100 mg/L) also showed positive effects, and maximum results were achieved when they were applied together.

The use of Corifol, a biostimulant developed from pyrolysis acid derived from agricultural waste, at a rate of 2 gal/acre effectively stimulated growth and increased soybean yield (Noel et al., 2024). Further analysis of the grain revealed higher protein and lysine content, while saturated fatty acid levels decreased.

The phytostimulant Stimulat, which contains a balanced blend of auxins, cytokinins, and gibberellins, was found to have positive effects on critical agronomic traits such as bean number, growth rate, yield index, and total yield (Viana et al., 2023).

Noel et al. (2021) carefully evaluated the effects of various liquid extracts of seaweeds (including Padina minor, Sargassum crassifolium, Sargassum cristaefolium, and Turbinaria decurrens) on the vegetative growth of soybean. Their findings showed that Padina minor extract was the most effective, leading to a significant increase in plant height, leaf number, and fresh biomass.

Experiments conducted in Brazil by Meyer et al. (2021) demonstrated that the application of Ecklonia maxima extract at doses ranging from 250–1000 ml/ha at the V4, R1 and V4+R1 growth stages significantly improved morphological traits and consistently increased soybean yield.

De Lima et al. (2024) specifically investigated the effects of foliar application of nicotinamide at doses of 100–600 mg/l. Their results clearly indicated an increase in plant height, number of branches, 1000-seed weight and total yield, highlighting its potential as a biostimulant.

Morais et al. (2022) investigated the efficacy of biostimulants under different moisture conditions. Although no significant effects were observed under severe drought, biostimulants significantly improved 1000-seed weight and total yield under normal moisture conditions.

The optimal three-stage application strategy, including seed treatment, V5 and R1 stages, was identified as the most effective.

Burkitbaev et al. (2021) focused on the effectiveness of sulfur-containing agrochemicals in different formulations. Their study concluded that powder and soluble forms gave the best results in terms of growth, yield and protein composition, while the paste form was ineffective.

Chen et al. (2023) investigated the complex effects of gibberellic acid A3 and mepiquat chloride on the symbiotic relationships between soybean and Sinorhizobium fredii and Bradyrhizobium japonicum. They found that gibberellic acid promoted nodule formation but simultaneously suppressed the activity of nitrogen-fixing enzymes, an inhibition that was partially reduced by mepiquat. The combined use of these substances led to improvements in yield, grain nitrogen content, nitrate reductase activity and other key biochemical parameters.

Alves et al. (2025) specifically investigated the effects of thiamine and nicotinamide applied at the V3 growth stage. All treatments tested resulted in increased plant height and yield, thereby confirming their significant potential as effective biostimulants for soybean.

Tkachuk et al. (2024) conducted an analysis in the Forest-Steppe of Ukraine, evaluating the effectiveness of Rhizohumin-Plus inoculation in combination with different concentrations of the retardant chlormequat chloride (0.5%, 0.75%, 1%) on soybean varieties “Azimut” and “Golubka”. The optimal dose of 0.75% was found to be the most effective, providing high plant density, sustained symbiotic activity, and impressive yields—in particular, 2.43 t/ha for Azimuth and 2.67 t/ha for Golubka. Solomichuk and Pikovsky (2021) carefully determined the optimal combinations of various biological products. They found that a specific mixture of BioMag Soya + BioPhosphorin + PhytoDoctor + Start Urozayu significantly improved photosynthetic activity, increased vegetative indices, and increased disease resistance. Effective use of such integrated biological systems has the potential to reduce dependence on conventional chemical crop protection while ensuring stable and high soybean yields.

Conclusions

The data presented here highlight the crucial role of bioactive substances, particularly plant growth promoters, as indispensable tools for achieving sustainable soybean production in modern agriculture. These environmentally friendly alternatives to conventional agrochemicals offer a promising avenue for enhancing crop resilience and productivity. The global importance of soybean requires continued attention to strategies that can improve its performance, especially in the face of increasing abiotic stresses caused by climate change.

This review of the scientific literature consistently demonstrates that the application of natural biostimulants—including seaweed extracts, amino acids, and microbial inoculants—significantly enhances the physiological and biochemical adaptive mechanisms of soybean. These substances optimize water use efficiency, strengthen antioxidant defense systems, and improve the uptake of essential mineral nutrients, ultimately resulting in more robust plants that are able to withstand adverse conditions such as drought, heat, and soil salinity.

Numerous studies from different agroclimatic regions, including specific studies from Ukraine, confirm the tangible benefits of these biostimulants. Whether used alone or, more effectively, in combination with microbial inoculants, they consistently lead to significant improvements in key agronomic parameters. These benefits include increased leaf area, plant height, bean number, seed weight and overall yield. In addition, the use of biostimulants has been shown to improve grain quality by increasing protein and lysine content, while potentially reducing undesirable components such as saturated fatty acids. Synergies have been observed when combining growth stimulants with inoculants, for example, positive interactions between different stimulants and BioMag Soybean or Rhizogumin-Plus with retardants, highlighting a powerful strategy for maximizing symbiotic activity and overall plant performance.

In essence, integrating these bioactives into soybean cultivation practices is a proactive and effective approach to crop management. This not only contributes to sustainable yield increases and improved grain quality, but also significantly reduces the dependence on traditional agrochemicals. This is ideally aligned with the principles of sustainable agriculture, contributing to more resilient cropping systems and enhancing soybean’s critical adaptability to unpredictable and changing climate conditions.

Going forward, further research into optimal formulations, application timing, and synergistic combinations will allow us to fully unlock the full potential of these valuable biological tools for a more sustainable and productive future of soybean cultivation.

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ВПЛИВ РОСТОСТИМУЛЮЮЧИХ РЕЧОВИН НА РІСТ ТА ПРОДУКТИВНІСТЬ СОЇ

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У сучасному сільськогосподарському виробництві зростає інтерес до біодобрив та біологічно активних речовин, зокрема стимуляторів росту рослин, як екологічно безпечних альтернатив традиційним агрохімікатам. Соя, будучи провідною продовольчою та кормовою культурою, відіграє ключову роль у глобальній продовольчій безпеці. Це дослідження аналізує ефективність різних стимуляторів росту на продуктивність сої, зосереджуючись на польових випробуваннях.

Вивчення впливу стимуляторів росту на врожайність, якість продукції та адаптивність сої до стресових умов є надзвичайно актуальним, особливо в контексті змін клімату в Україні. Огляд наукових даних, опублікованих у 2021-2025 роках, включає понад 30 досліджень з України, Бразилії, Іраку та Південно-Східної Азії. Проаналізовані біостимулятори включають екстракти морських водоростей, амінокислоти, вітаміни (фолієва кислота, нікотинамід, тіамін), мікробні інокулянти (BioMag, Rhizogumin-Plus) та синтетичні фітогормони. Результати показують, що ці речовини активують фізіологічні та біохімічні адаптаційні механізми, підвищують ефективність використання води, зміцнюють антиоксидантні системи та покращують засвоєння поживних речовин. Зокрема, комбіноване застосування стимуляторів росту та інокулянтів продемонструвало значне підвищення площі листкової поверхні, висоти рослин, кількості бобів, маси насіння та загальної врожайності.

Використання біостимуляторів також покращує якість зерна, збільшуючи вміст білка та лізину. Інтеграція цих біологічних речовин у технології вирощування сої є ефективним та стійким підходом, що сприяє підвищенню врожайності, покращенню якості продукції та зменшенню залежності від традиційних агрохімікатів, узгоджуючись з принципами сталого сільського господарства.

Ключові слова: соя, біостимулятори, стимулятори росту рослин, урожайність, стресостійкість, стале сільське господарство.

Отримано: 5.6.2025
Погоджено до друку: 25.11.2025
Опубліковано: 30.12.2025