EARLY PHENOLOGICAL AND GROWTH RESPONSES OF COTTON (GOSSYPIUM HIRSUTUM L.) TO HUMIC-BASED BIOSTIMULANTS UNDER VARIABLE PLANTING DENSITIES

Ergashboev Shokhrukhbek Sherzodjon ugli
PhD Researcher (Basic Doctoral Student) at the Department of Efficient Use of Household Lands and Medicinal Plants Agrarian Joint Faculty, Fergana State University
E–mail: Shohruhbekergashboyev@gmail.com
Orcid number: 0009-0004-1990-3274
Davronov Qaxramonjon Anvarjonovich
Doctor of Sciences in Agricultural Sciences (DSc) , Fergana State University,
E-mail: davronov2912@mail.ru
Phone number:+998936437912
Orcid number: 0000-0002-4083-2771

Abstract. *The regulation of early plant development plays a decisive role in determining the productivity and adaptability of cotton under intensive cultivation systems. This study investigates the influence of humic-based biostimulants—Ekogumin, a soil-applied humic acid formulation, and Novogumin, a foliar-applied fulvic acid complex—on the phenological development of cotton under varying planting densities. Field experiments were conducted in the irrigated conditions of the Fergana Valley during the 2025 growing season, employing a factorial design that included twelve treatment combinations across three plant population densities.*

Phenological parameters, including plant height, number of branches, flowering intensity, and boll formation, were systematically recorded from June to September. The results demonstrate that humic-based treatments significantly accelerate both vegetative and reproductive development. The combined application of Ekogumin and Novogumin produced the most pronounced effects, enhancing plant height by up to 10% during early growth stages and increasing reproductive indicators by 5–10% compared to untreated controls. These improvements were especially evident during the transition from vegetative to reproductive phases, suggesting enhanced physiological activity and metabolic efficiency. The findings confirm that humic substances play a critical role in optimizing growth dynamics and improving plant adaptability under conditions of increased population density.

Keywords: *cotton phenology, humic substances, plant development, biostimulants, growth regulation, planting density*

1. Introduction

The phenological development of agricultural crops represents a fundamental biological process that determines both yield formation and plant adaptability to environmental conditions. In cotton cultivation, early-stage growth and the timely transition from vegetative to reproductive phases are particularly critical, as they influence boll formation, maturation rate, and overall productivity. Under modern agricultural conditions, these processes are increasingly affected by soil degradation, nutrient imbalances, and climatic variability, all of which necessitate the development of more efficient and sustainable agronomic strategies.

In this context, humic substances—specifically humic and fulvic acids—have emerged as important components of biologically active fertilization systems. Derived from the decomposition of organic matter, these compounds are known to exert multiple physiological effects on plants, including stimulation of root development, enhancement of nutrient uptake, and regulation of enzymatic and hormonal activity. Unlike conventional mineral fertilizers, humic-based biostimulants do not merely supply nutrients but actively influence plant metabolism and growth processes.

Previous studies have demonstrated that humic substances can significantly improve plant growth parameters across a range of crops. For instance, Canellas et al. (2015) and Nardi et al. (2016) reported that humic acids enhance root architecture and increase nutrient use efficiency through hormone-like mechanisms. Similarly, Trevisan et al. (2010) highlighted the role of humic substances in modulating plant signaling pathways and improving stress tolerance. In cotton, Ali et al. (2023) observed that foliar application of fulvic acid promotes flowering and enhances resistance to abiotic stress conditions.

Despite these advances, the majority of existing research has focused primarily on yield outcomes, with comparatively limited attention given to the **temporal dynamics of plant development**, particularly during early growth stages. Moreover, the combined effects of soil-applied humic formulations and foliar-applied fulvic compounds under varying planting densities remain insufficiently explored.

Therefore, the present study aims to investigate the influence of Ekogumin and Novogumin on the phenological development of cotton, with particular emphasis on early vegetative growth, flowering initiation, and boll formation. By analyzing these processes under different plant population densities, the study seeks to provide a deeper understanding of how humic-based biostimulants regulate growth dynamics and improve plant performance under field conditions.

2. Materials and Methods

The field experiment was conducted during the 2025 growing season in the irrigated agricultural zone of the Fergana Valley, characterized by typical loamy soils and continental

climatic conditions. Cotton variety was selected as the experimental crop due to its widespread cultivation and responsiveness to agronomic interventions. Sowing was carried out in late May following standard regional practices.

The experimental design was based on a factorial arrangement that incorporated three levels of planting density—150–160, 180–190, and 210–220 thousand plants per hectare—and four fertilization treatments. These treatments included a control group receiving only standard mineral fertilizers, a soil application of Ekogumin, a combined application of Ekogumin and Novogumin, and a foliar application of Novogumin alone. Each treatment was replicated three times, and individual plot sizes were maintained at 277.78 m² to ensure statistical consistency.

Ekogumin, a humic acid-rich soil amendment, was applied prior to planting to enhance soil structure and nutrient availability. Novogumin, a liquid biostimulant containing fulvic acids, amino acids, and beneficial microorganisms such as *Bacillus* and *Trichoderma* species, was applied as a foliar spray during key growth stages, including vegetative development and early flowering.

Phenological observations were conducted at monthly intervals from June to September. Data collection focused on key growth indicators, including plant height, number of true leaves during early stages, number of productive branches, flowering intensity, and boll formation. Measurements were taken from randomly selected plants within each plot to ensure representative sampling. The collected data were averaged across replicates, and relative differences between treatments were expressed as percentages compared to the control.

3. Results and Discussion

The results of the study indicate that the application of humic-based biostimulants had a measurable and consistent impact on the phenological development of cotton throughout the growing season. During the early vegetative stage in June, differences among treatments were relatively modest but already evident. Plants treated with Ekogumin and Novogumin exhibited slightly greater height and branching compared to control plants, suggesting an early stimulation of root activity and nutrient uptake.

As the plants progressed into the flowering initiation stage in July, the effects of the treatments became more pronounced. The combined application of Ekogumin and Novogumin resulted in the highest increases in plant height and number of productive branches, indicating improved vegetative vigor and a more efficient transition to reproductive development. The enhancement of flowering intensity observed in treated plants suggests that fulvic acids may play a role in regulating hormonal processes associated with flowering initiation.

During the boll formation stage in August, significant differences were observed in reproductive performance. Plants receiving the combined treatment consistently produced a greater number of bolls compared to both the control and single-treatment variants. This indicates that the synergistic interaction between soil-applied humic substances and foliar-applied fulvic compounds enhances reproductive efficiency, likely through improved nutrient allocation and metabolic activity.

At the final maturity stage in September, treated plants maintained their developmental advantage. Increased plant height, higher numbers of opened bolls, and improved overall plant structure were observed, particularly in the combined treatment. These findings suggest that the effects of humic substances are not limited to early growth stages but persist throughout the plant lifecycle.

Planting density also played a significant role in shaping growth dynamics. Higher densities led to increased competition among plants, resulting in slightly reduced individual plant size. However, the application of humic-based biostimulants mitigated these effects by enhancing nutrient availability and improving physiological efficiency. This interaction indicates that humic substances can help stabilize plant development under conditions of increased population pressure.

From a physiological perspective, the observed improvements can be attributed to several mechanisms. Humic substances are known to stimulate root elongation and branching, thereby increasing the plant’s capacity for nutrient absorption. Additionally, their hormone-like activity can enhance cell division and elongation, leading to increased plant height and biomass accumulation. The presence of beneficial microorganisms in Novogumin further contributes to improved soil–plant interactions, enhancing nutrient cycling and plant health.

4. Conclusion

The findings of this study demonstrate that humic-based biostimulants significantly influence the phenological development of cotton, particularly during early and transitional growth stages. The combined application of Ekogumin and Novogumin proved to be the most effective treatment, promoting enhanced vegetative growth, improved flowering, and increased boll formation.

These results highlight the importance of considering plant development dynamics, in addition to yield outcomes, when evaluating the effectiveness of agricultural inputs. The use of humic substances offers a promising approach to improving crop performance under varying planting densities while supporting sustainable agricultural practices.

Future research should focus on detailed physiological analyses, including photosynthetic efficiency and enzymatic activity, as well as long-term studies to evaluate the cumulative effects of humic-based treatments on plant development and soil health.

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