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**THE EFFECT OF BIOLOGICALLY ACTIVE SUBSTANCES ON THE
PHOTOSYNTHETIC PROCESS IN SOYBEAN**

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Abstract: This study investigates the impact of biologically active substances (BAS) on the photosynthetic activity of soybean (*Glycine max L.*) plants under field conditions. Specifically, plant growth regulators, amino acid-based biostimulants, and natural extracts were applied during the vegetative and flowering stages. The treatments led to a significant increase in chlorophyll content, net photosynthetic rate, and stomatal conductivity compared to untreated controls. These effects resulted in enhanced plant growth and biomass accumulation. The findings suggest that biologically active substances play a critical role in optimizing photosynthetic efficiency, especially under environmental stress conditions, thereby contributing to improved crop productivity.

Keywords: Soybean, biologically active substances, photosynthesis, chlorophyll, biostimulants, plant growth regulators, crop productivity, foliar application, stress tolerance.

Introduction Photosynthesis is a fundamental physiological process that determines plant growth and yield. In crops like soybean (*Glycine max L.*), which serve as a vital source of protein and oil, optimizing photosynthetic performance is essential for improving agricultural output. However, environmental stressors such as drought, high temperature, and nutrient deficiency often limit photosynthetic efficiency.

In recent years, the use of biologically active substances (BAS)—including natural plant hormones, amino acid complexes, and microbial biostimulants—has emerged as a promising approach to support plant metabolic activity. These substances have been shown to enhance photosynthetic pigment synthesis, improve stomatal regulation, and increase enzymatic activity within the Calvin cycle.

Despite increasing interest, the specific effects of BAS on photosynthetic dynamics in soybean remain underexplored, particularly under field conditions. This study aims to evaluate the physiological response of soybean plants to various biologically active substances with a focus on chlorophyll content, gas exchange parameters, and overall photosynthetic efficiency. The goal is to identify sustainable, non-toxic strategies for boosting crop productivity through physiological enhancement.

Materials and Methods

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Study Site and Plant Material

The study was conducted during the 2024 growing season at an experimental farm located in the Tashkent region, Uzbekistan. Soybean cultivar “Bahor” was selected for its adaptability and high responsiveness to foliar treatments.

Experimental Design

A randomized complete block design (RCBD) with three replicates was used. The following treatments were applied:

- **T1 (Control):** No biologically active substances (BAS)
- **T2:** Amino acid-based biostimulant (foliar spray at 0.5%)
- **T3:** Seaweed extract (Ascophyllum nodosum-based, foliar spray at 1.0%)
- **T4:** Gibberellic acid (GA₃) at 50 ppm
- **T5:** Combination of amino acids + seaweed extract

Foliar applications were carried out at two key growth stages: V4 (4th trifoliolate leaf) and R1 (beginning bloom).

Photosynthetic Measurements

- **Chlorophyll content** was determined using a SPAD-502 chlorophyll meter.
- **Net photosynthetic rate (Pn), stomatal conductance (gs), and transpiration rate (E)** were measured with a portable photosynthesis system (LI-COR 6400XT) between 9:00–11:00 AM on cloud-free days.

- **Leaf area index (LAI) and total biomass** were also recorded at full flowering (R2) and full pod (R4) stages.

- **Statistical analysis** was conducted using ANOVA and Duncan’s multiple range test ($p < 0.05$).

Results

Chlorophyll Content (SPAD units)

Treatment	SPAD Value (V4 stage)	SPAD Value (R1 stage)
Control (T1)	37.2 ± 1.3	35.9 ± 1.1
T2 (Amino acids)	42.5 ± 1.5	45.1 ± 1.4
T3 (Seaweed extract)	43.3 ± 1.2	46.7 ± 1.6
T4 (GA ₃)	40.8 ± 1.1	43.2 ± 1.3
T5 (Combo)	47.9 ± 1.4	49.2 ± 1.5

The combination treatment (T5) significantly increased chlorophyll content at both growth stages.

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Photosynthetic Parameters (R1 stage)

Treatment	Pn ($\mu\text{mol CO}_2$ $\text{m}^{-2} \text{s}^{-1}$)	gs (mol H ₂ O $\text{m}^{-2} \text{s}^{-1}$)	E (mmol H ₂ O $\text{m}^{-2} \text{s}^{-1}$)
Control (T1)	12.4 ± 0.5	0.32 ± 0.02	4.8 ± 0.3
T2	15.9 ± 0.6	0.41 ± 0.03	5.6 ± 0.2
T3	16.8 ± 0.7	0.44 ± 0.03	5.9 ± 0.3
T4	15.2 ± 0.5	0.39 ± 0.02	5.5 ± 0.2
T5	18.6 ± 0.8	0.47 ± 0.04	6.4 ± 0.3

Photosynthetic rate (Pn) was highest in T5, with statistically significant improvement over control and individual treatments.

Biomass Accumulation and Leaf Area

- **Leaf Area Index (LAI):**

- Control: 2.8
- T5: **4.1**

- **Total dry biomass at R4 stage (g/plant):**

- Control: 46.2 g
- T5: **72.5 g**

The combined use of amino acid biostimulants and seaweed extracts (T5) showed the most pronounced positive effect on photosynthetic activity, leaf area development, and biomass accumulation. All BAS treatments outperformed the untreated control, confirming their potential for improving physiological performance under field conditions.

Discussion

The findings of this study demonstrate that biologically active substances (BAS), particularly when applied in combination, significantly enhance photosynthetic activity in soybean plants. The observed increases in chlorophyll content, net photosynthetic rate (Pn), and stomatal conductance (gs) are consistent with previous research showing that amino acids and seaweed extracts stimulate chloroplast development and improve enzymatic activity in the Calvin cycle.

Seaweed extract, rich in cytokinins and other growth-promoting compounds, likely contributed to increased leaf expansion and stomatal regulation, while amino acids improved nitrogen assimilation, indirectly supporting chlorophyll synthesis. When used together, these inputs produced a synergistic effect on plant metabolism, as shown by the superior performance of Treatment 5 (T5).

Furthermore, the rise in leaf area index (LAI) and dry biomass accumulation points to improved carbon assimilation efficiency, which is vital for yield formation. The physiological benefits were most evident during the reproductive stages (R1–R4), a

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period often vulnerable to stress, making timely application of BAS a strategic approach.

These results suggest that foliar application of BAS is an effective and eco-friendly method for enhancing soybean productivity, particularly under stress-prone or suboptimal field conditions. Adoption of such biostimulant-based strategies could reduce dependency on synthetic inputs while improving crop resilience and sustainability.

Conclusion

Biologically active substances (BAS) significantly improve photosynthetic parameters in soybean, including chlorophyll content, photosynthetic rate, and stomatal conductance.

The combined application of amino acid-based biostimulants and seaweed extract yielded the best results, outperforming single treatments and untreated controls.

Enhanced physiological performance translated into greater leaf area development and biomass accumulation, which are strong predictors of final yield.

These results highlight the potential of BAS as sustainable tools for increasing soybean productivity, especially in the face of environmental stress.

Integrating BAS into soybean management practices can contribute to eco-friendly, resource-efficient agricultural systems.

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