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Bibliographic review

Application of Cuban biostimulants in the rice cultivation (*Oryza sativa* L)

Aplicación de bioestimulantes cubanos en el cultivo del arroz (*Oryza sativa* L)

Aida Tania Rodríguez Pedroso*, **Miguel Ángel Ramírez Arrebato**, **Yosleidy Valle Fernández**

Unidad Científico Tecnológica de Base Los Palacios, Instituto Nacional de Ciencias Agrícolas, Carretera La Francia Km 1½, Los Palacios Pinar del Río, CP. 22900, Cuba.

ABSTRACT: In modern agriculture, intensive efforts are underway to identify products that enhance crop growth and development, as well as increase yields. Preference is given to those of natural origin, biodegradable, and environmentally safe. Rice (*Oryza sativa* L.) is among the crops where the application of biostimulants has been researched actively, demonstrating positive effects on germination, vegetative growth, and productivity. Among the biostimulants studied are commercial formulations such as Biobras-16®, FitoMas E®, Pectimorf®, Liplant®, Quitomax®, and plant extracts. The objective of this review is to present the results of the effects of several biostimulants developed in Cuba and applied to rice cultivation, including their dosages, timing of application, and potential to increase yields. These products represent a viable alternative to promote plant growth and development while enhancing resistance to stress conditions.

Key words: biocomposites, growth, germination, yield.

RESUMEN: En la agricultura actual se trabaja intensamente en la búsqueda de productos que permitan favorecer el crecimiento y desarrollo de los cultivos, así como aumentar los rendimientos, siendo recomendables aquellos de origen natural, biodegradables y no causen daños al medio ambiente. El arroz (*Oryza sativa*, L.) es uno de los cultivos en los que se ha venido investigando la aplicación de bioestimulantes y el efecto positivo sobre su germinación, crecimiento y rendimiento. Entre ellos, se encuentra Biobras-16®, FitoMas E®, Pectimorf®, Liplant® Quitomax® y los extractos vegetales. El objetivo de esta revisión es mostrar los resultados del efecto de algunos bioestimulantes obtenidos en Cuba aplicados al cultivo del arroz. Así como, sus dosis, momentos de aplicación y su potencial para incrementar los rendimientos. Por lo que, constituyen una alternativa viable para potenciar el crecimiento y desarrollo de las plantas y entregar mayor resistencia a las condiciones de estrés

Palabras claves: biocompuestos, germinación, rendimiento, crecimiento.

INTRODUCTION

The future of agriculture lies in feeding a growing global population while confronting climate change, rising temperatures, and droughts factors that underscore the need for crops with enhanced resistance to pests and diseases, higher yields, and the use of environmentally friendly products. Furthermore, the accelerated degradation of agroecosystems due to poor agricultural management, among other factors, compels the agro-industrial sector to seek and formulate new and improved natural products that enable sustainable agricultural production and healthier food sources (1).

Currently, the use of biostimulants in agriculture has increased internationally, yielding highly promising results for making agriculture more sustainable in the new millennium (2).

*Author for correspondence. atania@inca.edu.cu

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In Cuba, research into the development, characterization, and application of biostimulants in economically significant crops has been ongoing since the late 1980s. Among these crops is rice (*Oryza sativa* L.), which since 1967 has held a prominent role in the country's economic plans due to its high annual per capita consumption within Cuban society (3).

Rice cultivation requires substantial application of mineral fertilizers and pesticides. However, scientific evidence has shown that the indiscriminate use of synthetic chemicals not only entails high costs but also leads to reduced biodiversity, increased risks of salinization and depletion of essential nutrients, alterations in soil acidity, and overall degradation of soil quality (4, 5).

Given this scenario, it is essential to explore more cost-effective fertilization strategies for various crops, such as the use of biofertilizers, organic amendments, and plant growth biostimulants. These alternatives contribute to plant nutrition, improve the physical, chemical, and biological properties of the soil, and positively influence the physiological activity of plants (6-8).

Bioestimulants

Agricultural biostimulants are among the oldest products used in farming; however, their widespread application did not begin until the 1990s (9). They are defined as any substance of biological or organic origin, or a group of beneficial microorganisms, that when applied to plants, enhance nutrient uptake and assimilation, improve tolerance to biotic and abiotic stresses, and renew certain agronomic traits regardless of their nutrient content (10, 11). Biostimulants also stimulate and invigorate plants from germination to fruiting, shorten the crop cycle, and increase overall yield (12).

These bioproducts further promote root development, expanding the surface area for water and nutrient absorption. They foster beneficial microorganisms that break down nutrients into more accessible forms for plants, balance soil pH, improve soil structure, and support healthy crop development while protecting against soil-borne diseases (13). Thanks to their effects, biostimulants help plants withstand stress and adverse environmental changes. This is attributed to the multi-omics approach, which has advanced our understanding of biostimulant action at the cellular level, where they function as signal transduction messengers similar to phytohormones and other chemical compounds that mitigate environmental impacts and contribute to food security (14, 11).

Biostimulants fall into several categories, including marine and plant extracts, microbial agents (beneficial fungi and bacteria), humic substances, amino acids and peptide blends, chitosans, other polymers, and inorganic compounds (10, 11, 15).

In Cuba, the use of biostimulants plays a crucial role both economically and environmentally. Economically, they reduce agricultural input costs by replacing imported products with locally manufactured alternatives derived from domestic raw materials. Environmentally, they protect plants from stress, reduce dependence on chemical fertilizers and pesticides, and promote ecological health and resilience. These products pose no contamination risk to the environment or human health, offering a pathway toward sustainable agriculture (9).

Among the biostimulants produced and used in Cuba are:

Biobras-16®, whose active ingredient is a spirostanic analogue of brassinosteroids an organic compound with proven stimulatory effects that positively, influences agricultural yields. The Natural Products Laboratory of the Faculty of Chemistry at the University of Havana, with a concentration of 1 g L^{-1}, produces it (16).

FitoMas E®, a novel derivative from the Cuban sugar industry, exhibits strong anti-stress properties and biostimulant effects by enhancing crop growth and development. The Cuban Institute developed it for Research on Sugarcane Derivatives (ICIDCA). The product is a natural cocktail of high-energy organic intermediary substances, including amino acids, low molecular weight peptides, nitrogenous bases, and carbohydrates (17).

Pectimorf®, recognized as a Cuban bioregulator, is derived from citrus industry residues. Its active ingredient is a mixture of pectic-origin oligosaccharides, developed by the Bioactive Products Group of the National Institute of Agricultural Sciences (INCA). Pectimorf® has demonstrated the ability to induce rooting and significantly enhance the development and vigor of *in vitro* plants across various crops, validating its promise in plant biotechnology (18, 19).

Liplant®, a plant biostimulator and nutrient carrier, contains Ca, Mg, Na, P_2O_5, K, N, free amino acids, polysaccharides, carbohydrates, inorganic elements, humified substances, beneficial microorganisms, plant hormones, and soluble humus. The Agrarian University of Havana (UNAH) from vermicompost (20) produces it.

Quitomax®, a liquid bioproduct whose main active component is chitosan polymers. This biostimulant is applied to various crops, enhancing their development and quality. It is a commercial product of the National Institute of Agricultural Sciences (INCA) (21, 22).

Plant extracts with biostimulant activity contain a wide range of bioactive compounds that enhance most physiological processes, stimulate growth and development, and increase the final crop yield (23).

Rice cultivation

Rice (*Oryza sativa* L.) is the staple food for more than half of the global population and it is considered the most important crop worldwide due to the vast area under cultivation and the number of people dependent on its harvest. It is one of the most widely cultivated cereals globally, with an average annual production of approximately 523.73 million tons. Asia, led by China and India, dominates global rice production, together accounting for over half of the total output, followed by the Americas with 37 million tons (5 % of the global total), underscoring the strategic importance of rice production for many countries in the region.

In Cuba, rice is a key component of the daily diet, with a per capita consumption estimated at 80.38 kg annually, one of the highest in Latin America (24).

However, yields remain low at 2.61 t ha^{-1} due to various biotic and abiotic factors, including pests, diseases, climatic variability, drought, and salinity. Additionally, rising production costs driven by increased prices of key agricultural inputs pose further challenges. Science and technology must be applied to achieve more sustainable, efficient, and environmentally protective agricultural practices. Cuba has launched a development program aimed at gradually achieving national self-sufficiency in rice production (25). Among the current outcomes of Cuban agriculture, the use of natural, non-toxic products derived from domestic raw materials through cost-reducing methodologies is crucial for increasing yields on the same cultivated area with equal or reduced applications of expensive imported fertilizers and pesticides (26).

Use of biostimulants in rice cultivation

The effectiveness of Cuban biostimulants in rice cultivation depends on dosage and timing of application.

In the INCA LP 2 cultivar, two doses (20 and 50 mg ha^{-1}) of Biobras-16® were applied during different stages across two growing seasons cold and spring. A significant yield increase was observed during the cold season, specifically in the number of panicles per square meter. In the spring season, improvements were noted in the same variable, as well as in the number of filled grains per panicle and the weight of 1,000 grains (27). Other researchers applied three doses (20, 50, and 100 mg ha^{-1}) of Biobras-6 to the same cultivar across both seasons and different growth stages. The best results were obtained with a 50 mg ha^{-1} dose split equally between active tillering and panicle initiation (cold season), and between panicle initiation and grain filling (spring season) (28).

In vitro studies combining brassinosteroid analogs and growth regulators showed that BB-6 could replace cytokinins in regenerating rice plants from callus tissue of the Amistad-82 and INCA LP 10 varieties, significantly stimulating cellular differentiation (29).

Among biostimulants, oligogalacturonides are compounds capable of triggering defense responses and regulating plant growth. Some authors applied different concentrations (0, 10, and 20 mg L^{-1}) of a mixture of oligogalacturonides (MOGs) to rice seeds of the INCA LP 7 cultivar for 24 hours and to Hoagland nutrient solution supplemented with 100 mmol L^{-1} NaCl (30). Salinity-treated plants showed reduced shoot and root length, while those treated with 20 mg L^{-1} MOGs exhibited the opposite response, along with increased leaf peroxidase activity and reduced proline concentration, indicating lower stress and better acclimatization to saline conditions.

QuitoMax® was applied to rice cultivars J-104 and INCA LP 5 at different stages and via various methods. The best results were observed when seeds were treated for 15 minutes and plants received two foliar applications of QuitoMax® (22, 31).

Other researchers evaluated the effects of different chitosan concentrations (100, 500, 1000, and 2000 mg L^{-1}), the active ingredient in QuitoMax®, on germination and seedling growth of the J-104 rice cultivar. Seeds imbibed at 1000 mg L^{-1} germinated faster than other treatments. For plant height, 2000 mg L^{-1} outperformed the control with statistically significant differences. This concentration also yielded the highest fresh leaf mass, with a trend of increasing biomass as chitosan concentration increased (32).

For Fitomas E®, researchers tested doses of 1.5, 2.0, and 2.5 L ha^{-1} on the Selección I cultivar and observed positive effects on vegetative growth (33), as well as on yield components (panicles per square meter, filled grains per panicle, and weight of 1,000 grains). The best results were achieved with 2.0 L ha^{-1}, yielding 5.82 t ha^{-1}, 29.8 g per 1,000 grains, 105.6 filled grains per panicle, and 422.6 panicles per square meter.

Humic acids extracted from vermicomposted cattle manure were applied at two concentrations (34 and 46 mg L^{-1}) under controlled and semi-controlled conditions to the IACuba 30 variety. Under controlled conditions, these compounds positively influenced germination, increasing root and root hair formation by up to 60 % compared to the control. Under semi-controlled conditions, peroxidase activity and protein content increased, indicating enhanced biosynthesis and amino acid utilization, demonstrating potential as a drought stress protector (34). Another study evaluated two humic substance extracts (ESH II and I) on the INCA LP 5 cultivar. While neither extract affected seed germination, ESH II increased radicle and coleoptile length. Both extracts positively influenced aerial growth (2).

Three aqueous plant extracts mulberry (*Morus alba*), willow (*Salix babylonica*), and a mixture of bothwere tested on seed germination of the INCA LP 5 cultivar in Granma province. After 48 hours of seed treatment, the willow extract achieved 96.0 % germination within six days (35).

Liplant® was evaluated for its effect on callogenesis and *in vitro* regeneration of rice cultivars INCA LP 5, IACuba 28, and LC88-66, aiming to improve the quality and quantity of material for genetic transformation. Liplant® enhanced the effect of 2,4-D on *in vitro* callogenesis. Lower concentrations favored plant regeneration in INCA LP 5, while no significant improvements were observed in the other two cultivars. These results suggest Liplant® as a complementary agent to 2,4-D in rice callus production for genetic transformation (36).

Pectimorf® was tested to determine its ability to stimulate germination of INCA LP 7 seeds under saline conditions. Seeds were soaked for 24 hours in different concentrations (10, 20, and 40 mg L^{-1}). Researchers found that 10 and 40 mg L^{-1} significantly increased final germination percentage and vigor index under salinity stress (37).

The industrial quality of rice grain was another parameter evaluated following the application of Biobras-16® and QuitoMax® biostimulants. The most effective application timing for QuitoMax® was achieved through pre-germination in a 1 g L^{-1} solution and foliar spraying at a dose of 360 mg ha^{-1}, 20 days after germination, resulting in a yield of 3.96 t ha^{-1}. For Biobras-16®, optimal results were obtained with pre-germination in water and foliar spraying at a dose of 10 mg ha^{-1}, 40 days after germination, yielding 3.85 t ha^{-1} in terms of industrial performance (38).

CONCLUSIONS

This review demonstrated that Cuban biostimulants, Biobras-16®, FitoMas E®, Pectimorf®, Liplant®, QuitoMax®, and various plant extracts are capable of stimulating multiple physiological processes in rice cultivation, both *in vivo* and *in vitro*. Their effects include enhanced callus formation, plant regeneration, seed germination, vegetative growth, and overall yield. The findings also emphasize the importance of dosage and timing of application in achieving optimal results.

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