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EFFECT OF THE COMBINED USE OF VIUSID agro® AND INIVIT BIOPROTEX® ON SWEET POTATO (*Ipomoea batatas* [L.] Lam.) PRODUCTION

Lilian Morales Romero[1], Alfredo Morales Rodríguez[2], Nilo J. Maza Estrada[3], Osmany Molina Concepción[4], and Bulent Kukurtcu[5]

[1, 2, 3, 4] Research Institute of Tropical Roots and Tuber Crops (INIVIT), Santo Domingo, Villa Clara, Cuba
[5] Scientific Advisor Catalysis, S.L. Madrid. España

Correspondence should be addressed to Lilian Morales Romero; lilimoralesro67@gmail.com

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ABSTRACT- The unavoidable increase in agricultural productivity to meet the food demand of a growing population, coupled with concerns over the excessive use of chemical inputs, is promoting the global development of bio-inputs for agricultural use. In Cuba, sweet potato is not only a food of cultural significance but also an ally for health. Achieving 630,000 tons annually constitutes an agricultural challenge that demands innovations aimed at increasing productivity. This study was conducted to determine the combined effect of a plant growth promoter developed in Spain and the nutritional supplement INIVIT BIOPROTEX® (RCF 002/25) on the production of sweet potato cultivar 'INIVIT B-50'. The combined application of VIUSID agro® (0.2 mL L^{-1}) + INIVIT BIOPROTEX® (10% of the final solution) demonstrated a significant effect on increasing the weight of commercial sweet potato roots, achieving a yield of 38.0 $t \cdot ha^{-1}$, which represents an increase of 16.1 $t \cdot ha^{-1}$ compared to the control. This evidences a synergistic effect between both bioproducts, enhancing plant growth, nutrition, and health. This innovation is fully aligned with the Cuban Program for Bioproducts of Agricultural Use, which is currently promoted as a solution for food production in our country.

KEYWORDS- Agro-Productivity, Biofertilizers, Sweet Potato, Tropical Root, Tuber Crops

I. INTRODUCTION

The world population is growing rapidly, meaning an increase to over nine billion people by 2050, or one-third more people to feed. Coupled with this, global agri-food systems are at a crucial juncture, facing unprecedented difficulties [1]. This situation demands a 60% increase in agricultural production [2]. Sweet potato (*Ipomoea batatas* [L.] Lam.), due to its short growth cycle, resilience to extreme climate, vegetative propagation, and drought tolerance, positions it as a key crop for food security in vulnerable tropical regions [3]. The challenges facing the world – climate change, food security, geopolitical trade crises, along with the growing demand for sustainable food production practices that harmonize with environmental goals – emphasize the need for sustainable food production based on environmental, social, and governance principles, and circular economy models [4]. The increasing global demand for food has generated strong pressure on agroecosystems. International reports have critically analyzed the social and environmental costs of food and agricultural systems [5]; this has led to the search for more sustainable strategies to improve agricultural productivity, meet food demand in a relatively short period, and thus guarantee food security [6]. Traditional agricultural models rely heavily on synthetic fertilizers and pesticides [7]. Approximately 53 billion tons of NPK fertilizers are used annually to supplement the nutrients necessary for plant growth and crop yield [6]. Concern over the excessive use of chemical fertilizers is a global concern [8].

Around the year 2018, Cuba received 350,000 tons of fertilizers, with a fertilization rate averaging 90 kilograms per hectare, placing it at an intermediate global standard. However, that capacity was reduced to zero. Today, Cuba has a program to consolidate the production strategy, both nationally and locally (the Bio-inputs Program). The combination of industrial plants and artisanal production makes it possible to respond to farmers' demands, even though current industrial bioproduct production covers between 45 and 50% of the national demand, ensuring a minimum of nutrients for crops to achieve reasonable yields and mitigating the shortage of chemical fertilizers [9].

Biostimulants act on the natural biochemical processes of plants. Produced from biological components, they help boost plant growth, quality, and productivity through the unique properties of their constituents, due to the presence of nutrients or growth regulators [10]. Especially those rich in amino acids have been developed and recognized for their positive effects on crops [11].

The need to increase productivity in sweet potato production areas, achieving commercial tuberous roots with damage percentages from the sweet potato weevil within permissible ranges for commercialization, led to this study.

The objective was to determine the combined effect of the plant growth promoter developed in Spain and the

nutritional supplement obtained at INIVIT (INIVIT BIOPROTEX® (RCF 002/25) on the production of sweet potato cultivar 'INIVIT B-50'.

II. MATERIALS AND METHODS

The research was conducted at the Research Institute of Tropical Root and Tuber Crops (INIVIT), located at 22° 35' N, 80° 18' W, at 40 meters above sea level, in the Santo Domingo municipality, Villa Clara province, Cuba. The soil is classified as Carbonated Smoothed Brown soil, according to the Cuban soil classification [12].

Propagation material consisted of cuttings from the cultivar 'INIVIT B-50' obtained from the Basic category Seed bank. Planting was carried out during the rainy period, known as the spring season, at a spacing of 0.90 x 0.30 m (37,037 cuttings per ha), occupying a total area of 184.68 m² and a net area of 158.68 m². Three plots (20.52 m² each) were established per treatment.

Three treatments were established randomly with three replicates:

A. Treatments and composition of the studied bio-inputs

T1: VIUSID agro® (0.2 mL L^{-1})

T2: Combined use of VIUSID agro® (0.2 mL L^{-1}) + INIVIT BIOPROTEX® at a concentration of 10% of the final solution (1.6 L/backpack sprayer)

T3: Control (where only water was applied)

The declared composition of the growth promoter VIUSID agro® [13] is described in Table 1.

Table 1: Composition of the growth promoter VIUSID agro®

Composition	Units
Aspartic Acid	1.6 %
Arginine	2.5 %
Glycine	2.4 %
Tryptophan	0.5 %
Organic Nitrogen 1.8%	1.8 %
pH	6.80
Density	1.14 Kg/L
Net mass	1.14 kg

The biofertilizer developed by INIVIT registered by the Ministry of Agriculture, Directorate of soils and fertilizers and Central Register of Fertilizers under the trade name INIVIT BIOPROTEX®, is compatible with other agricultural bio-inputs. The declared composition of the biofertilizer is: In %: Total Nitrogen 0.022; Total Carbon 0.19; Organic Matter 0.33, In mg/kg: P 204; K 12614; Ca 27; Mg 22; Na 53; Fe 0.64; B 1.2; Cu 0.35; Mn 1.7; Zn 0.24; Chlorides 491; Phosphates 153; Sulfates 164; Gram-positive spore-forming Bacillus, identified as *Bacillus* sp. [14].

Applications were performed weekly (every seven days starting 15 days after planting, carrying out 10 applications in total). A 16 L capacity backpack sprayer (Matabi, Spain) was used with a flood-jet nozzle (Lurmark AN 2.5) at a pressure of 1.5 to 2.0 bar. Crop management practices were carried out according to the Technical Guidelines for the crop. No chemical inputs were applied. At harvest time, the average weight of commercial roots (kg) was evaluated for agro-productivity analysis.

Statistical analyses were performed using the Kruskal-Wallis test, a non-parametric test used to compare two or more groups that are not normally distributed, to determine significant differences between the groups for the variable of interest.

III. RESULTS AND DISCUSSION

The result of the Kruskal-Wallis test for the variable Weight (kg) of commercial tuberous roots, with a chi-squared statistic, indicates a significant difference between the treatments (see Figure 1).

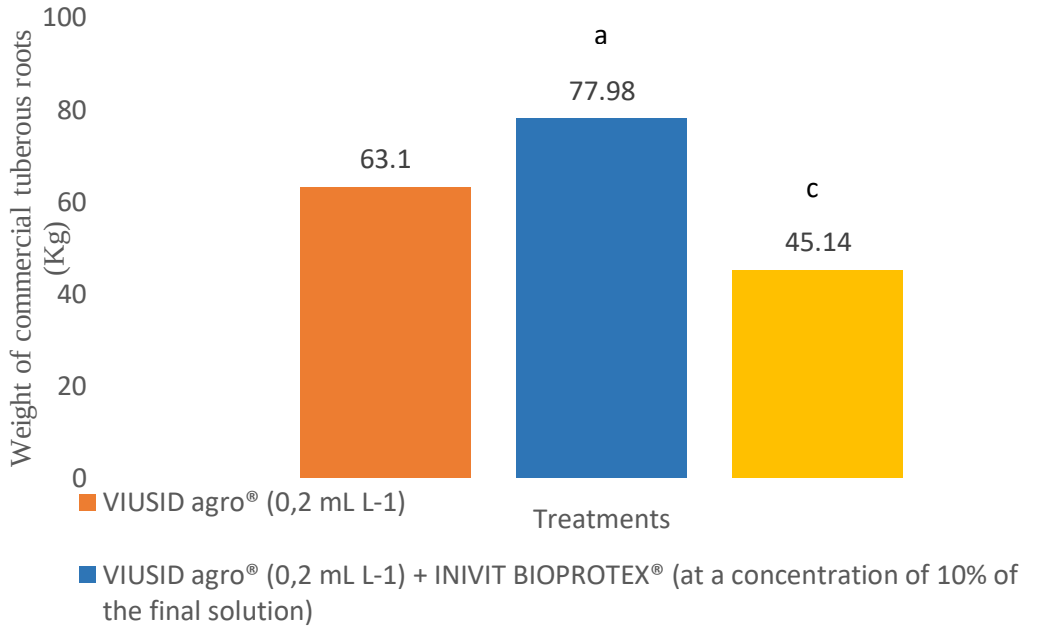

Figure 1: Weight (kg) of commercial tuberous roots of sweet potato, cultivar 'INIVIT B-50' in the studied treatments (Kruskal-Wallis chi-squared = 4.2839, df = 1, p-value = 0.03847)

The combined application of VIUSID agro® + INIVIT BIOPROTEX® has proven to be highly effective, evidencing a synergistic effect between both bioproducts, enhancing plant growth, nutrition, and allowed obtaining commercial roots with damage percentages from the sweet potato weevil (*Cylas formicarius*) within permissible ranges for commercialization. These results are associated with the use of the growth promoter based on amino acids and organic nitrogen, as numerous studies have reported the product's benefits on crop growth and yield [15]. The authors attribute this effect on productivity to the biostimulant's composition [16]. Foliar application of VIUSID agro® had a positive influence, probably due to the types of amino acids it contains and the lower amount of organic nitrogen. These factors have been linked to antioxidant and growth-stimulating effects, both under normal conditions and under abiotic stress [17]. Furthermore, foliar application of organic nitrogen in small doses stimulates plant growth, resulting in greater dry mass accumulation and higher yield [18].

The use of VIUSID® agro at a dose of 0.50 L/ha/application offered a significant influence on the variable Foliar Emission Rate, an essential variable for the quantitative analysis of plant growth. The number of leaves emitted per plant in the 'Cavendish gigante' cultivar every seven days was double that of untreated plants. The number of leaves emitted per plant every seven days can be modified by human intervention through the use of VIUSID® agro. With the application of VIUSID® agro, plants were able to reach flowering with a greater number of formed leaves, which constitute the source for fruit filling, with a significant influence on bunch weight [19].

VIUSID® agro has proven highly effective in various cereal and short-cycle vegetable crops, showing significant increases in yield and improvements in morphological variables. In garlic, yield increased by 65%, while in radishes it increased by 50%. In lettuce, a notable increase in fresh and dry biomass was observed, especially under hydroponic conditions. In cereal crops such as beans, maize, and rice, improvements were also recorded, highlighting a 42% increase in beans with a dose of 0.25 L ha^{-1}, without additional fertilizers [20]. On the other hand, INIVIT BIOPROTEX® (RCF 002/25), developed by INIVIT from waste from plantain and banana production (plantain rachis), constitutes an agroecological initiative aimed at crop nutrition [21]; [22]. It is a natural, 100% soluble liquid product, with a composition of macro and micronutrients and sporulated Gram-positive bacilli, identified as *Bacillus* sp. at a concentration of 4.4 x 10^6 CFU/mL [23]. It stimulates root, stem, and leaf growth, increases plant vigor, and by contributing to plant nutrition, it stimulates defense mechanisms that favor resistance to harmful agents [24]. In this regard, point to bacteria of the genus *Bacillus* as plant-protective bacteria; species of this genus are used as an alternative to chemically synthesized pesticides to protect crops against pest insect attacks [25]. In this sense, report that the use of the bioproduct developed at INIVIT suggests the possibility of its use as a novel alternative for the biocontrol of soil plant-parasitic nematode communities, by significantly reducing the galling index of root-knot nematodes of the genus *Meloidogyne* [24].

The effect of different organic fertilizers on sweet potato production in savanna soils of Roraima, Brazil, determined that each organic fertilizer used, regardless of the application rate, promotes higher percentages of commercial yield compared to the absence of organic fertilization [26].

The results obtained in this research indicate that the combined application of both bioproducts (VIUSID agro® + INIVIT BIOPROTEX®) demonstrates a high technical impact by significantly increasing the productivity of the sweet potato crop. A yield of 38.0 tons per hectare was achieved, representing an increase of 16.1 $t \cdot ha^{-1}$ compared to the untreated crop without additional fertilizers, representing a difference in production value of 3206.83 CUP (see Table 2). This 73.5% increase in yield is a notable technical advancement that optimizes the efficiency of the cultivated area. This increase in productivity directly translates into a greater volume of commercial roots harvested per hectare. For the farmer, this means an increase in economic income and a better cost-benefit ratio, as more food is obtained from the same land area and with the same investment in cultural practices.

Table 2: Agro-productive performance of cultivar 'INIVIT B-50' in the studied treatments

Treatments	Average weight of commercial roots (kg)	Equivalent Yield ($t \cdot ha^{-1}$)	Difference vs. Control ($t \cdot ha^{-1}$)	Production Value (CUP)	Difference vs. Control (CUP)
T1: VIUSID agro® (0.2 mL L^{-1})	63.61	30.9	9.0	6211.52	1803.60
T2: Combined use VIUSID agro® + INIVIT BIOPROTEX	77.98	38.0	16.1	7614.75	3206.83
T3: Control	45.14	21.9		4407.92	

*Retail price 97.65 CUP/kg (45.00 CUP/Lb), according to the List of Maximum Prices for Agricultural Products. August, 2025.

The results are similar to previous research that determined the economic viability of nutritional alternatives in sweet potato cultivation, cultivar INIVIT B-27-2017, and state that all treatments generated profits over the control, demonstrating the feasibility of using organic alternatives in the crop [27].

The growth promoter VIUSID Agro®, being a product that essentially contains amino acids, vitamins, and minerals that have undergone a biocatalytic molecular activation process to enhance its biological activity, makes it possible to favor the vegetative and reproductive phases of crops. It also increases stem length, as well as the number of leaves, and stimulates the number of flowers and fruits, positively influencing yield increases. Its combined use with the nutritional supplement INIVIT BIOPROTEX®, due to its composition, contributes to crop nutrition, stimulates root, stem, and leaf growth, increases plant vigor, and stimulates defense mechanisms

that favor plant resistance to pathogens. This action is enhanced by the microbial load it contains. These qualities of the two natural products made the increase in weight and health of commercial sweet potato roots possible. The future of integrating biostimulants and biofertilizers (combined formulations) is promising for improving sustainable agriculture. Further research is essential to better understand the synergistic mechanisms involved in improving sweet potato quality.

IV. CONCLUSION

The results obtained demonstrate that the synergistic combination of VIUSID agro® and INIVIT BIOPROTEX® is an effective alternative for substantially increasing sweet potato yields, exceeding conventional yields by more than 16 $t \cdot ha^{-1}$. This finding is particularly relevant in the Cuban context, where the Agricultural Bioproducts Program promotes sustainable technological solutions for food security.

Beyond the increased yields, the central contribution of this work lies in demonstrating that the integration of biostimulants from diverse sources can mutually enhance their effects on plant growth, nutrition, and health, opening new perspectives for the eco-intensive management of crops. From an applied perspective, the results support the recommendation to incorporate this mixture into commercial production systems, as well as its validation in other sweet potato varieties and in crops of interest to Cuban agriculture. It is also suggested to explore alternative doses and application frequencies that allow further optimization of the benefit-cost ratio, as well as to evaluate the impact of this technology in diverse soil and climate conditions in order to consolidate its scaling up.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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ABOUT THE AUTHORS

Lilian Morales Romero: Ph.D. in Agricultural Sciences; Master's Degree in Sustainable Agriculture**;** Degree in Phytosanitary Engineering

Professional Affiliation & Memberships: Senior Research Scientist and Pest Management, Research Institute of Tropical Roots and Tuber Crops (INIVIT). Full Academician, Academy of Sciences of Cuba. Full Professor, Faculty of Agricultural Sciences, Universidad Central Marta Abreu de las Villas

Research Work & Experience: With 33 years of experience as a researcher, Dr. Morales Romero specializes in the design of integrated pest management strategies. She currently serves as Director of Pest Management and leads the national Program for the Development of Bio-inputs for Agricultural Use. Her research focuses on sustainable agricultural solutions, with an emphasis on the development, validation, and implementation of biological products that enhance crop health and productivity while reducing reliance on chemical inputs

Key Achievements & Publications: Among her most significant contributions is the development and official registration of INIVIT BIOPROTEX®, a biofertilizer widely adopted in Cuban agriculture. She has authored numerous scientific publications related to biological pest control, plant nutrition, and sustainable agriculture, contributing substantially to the advancement of agronomic science in Cuba.ersonal profile which contains their education details, their publications, research work, membership, achievements, with photo.

Alfredo Morales Rodríguez: Master's Degree in Agricultural Sciences; Diploma in Molecular Genetics, Jiangsu Academy of Agricultural Sciences (JAAS), Nanjing, China; Degree in Agronomic Engineering

Professional Affiliation & Memberships

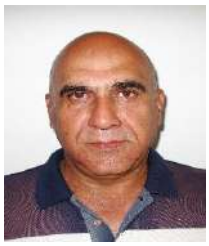
Senior Research Scientist and Plant Breeder, Research Institute of Tropical Roots and Tuber Crops (INIVIT)

Leader, Cuba's National Sweet Potato Breeding Program

Research Work & Experience: With over 13 years of experience in genetic improvement, stress physiology, and integrated pest management of tropical root and tuber crops, Mr. Morales Tejón leads Cuba's National Sweet Potato Breeding Program at INIVIT. His research focuses on developing high-yielding, resilient varieties adapted to local conditions, employing molecular genetics tools and conventional breeding techniques to address the challenges of food security and agricultural sustainability.

Key Achievements & Publications: He has spearheaded the development, registration, and release of 15 commercial varieties, including 8 sweet potato, 3 cassava, 1 yam, 1 pumpkin, and 2 cucumber varieties, achieving an average yield increase of more than 5 $t \cdot ha^{-1}$ per genotype. His most impactful contribution is the development of the sweet potato variety 'INIVIT B-50', which yields 10 $t \cdot ha^{-1}$ above commercial checks.

Since its release in 2015, this variety has occupied 34% of Cuba's national sweet potato area, representing a significant advancement in food security and agricultural productivity. His work has been widely recognized for its tangible impact on Cuban agriculture.



Nilo J. Maza Estrada: Master's Degree in Science and Innovation Management; Bachelor's Degree in Industrial Economics

Professional Affiliation & Memberships: Senior Research Scientist and agro-economic research, Research Institute of Tropical Roots and Tuber Crops (INIVIT)

Research Work & Experience: With 35 years of experience in agro-economic research, Mr. Maza Estrada specializes in the evaluation of economic impacts and the adoption dynamics of new agricultural technologies. His work bridges the gap between technological innovation and its practical application in the agricultural sector, providing critical insights for decision-making and technology transfer.

Key Achievements & Publications: He has led prominent studies on the adoption and socioeconomic impact of technological innovations in Cuban agriculture, with particular emphasis on sweet potato production systems. His research has been instrumental in understanding how new technologies, including bio-inputs and improved agronomic practices, translate into economic benefits for producers. His findings are widely referenced in policy discussions and agricultural development programs in Cuba.

Osmany Molina Concepción: B.S. in Computer Science, Technological University of Havana "José Antonio Echeverría" (CUJAE), Cuba, 1994

Postgraduate Studies in Computer Science, Universidad Central "Marta Abreu" de Las Villas (UCLV), Cuba, with specialized training in artificial neural networks, pattern recognition, bioinformatics, computational mathematics, advanced databases, and software engineering

Professional Affiliation & Memberships: Researcher, Research Institute of Tropical Root and Tuber Crops. (INIVIT), Cuba

Research Work & Experience: With over 25 years of experience in agricultural bioinformatics, Mr. Molina Concepción specializes in genetic data analysis, statistical modeling, and artificial intelligence applied to plant genetic resources. His research focuses on the development and application of multivariate statistical methods, machine learning, and artificial intelligence techniques in R for supervised and unsupervised classification of plant germplasm.

Key Achievements & Publications: He has participated in numerous research projects related to genetic diversity analysis, selection of minimal descriptors, and the development of reproducible analytical tools using open-source software. His scientific contributions support innovation in agricultural research through the integration of data science, artificial intelligence, and reproducible statistical methodologies, providing a robust computational foundation for crop improvement.

Bulent Kukurtcu: 1986 - Graduated with a degree in Biology, specializing in marine biology, from the University of Aegean, Izmir, Turkey. This diploma was officially recognized by the Ministry of Education in Spain in 1992. 1986 - Completed laboratory courses and gained practical experience in clinical biochemistry and parasitology at the Health Institute in Izmir, Turkey. 1987/88 - Undertook a master's program in Taxonomy at the Biology Department of the University of Istanbul. 2002/06 – Earned diploma in the Doctoral Programme of Advanced Studies of the Biodiversity Division of the Biology Department at the Autonomous University of Madrid (UAM).

Core Competencies Marine Biology and Aquaculture: Expert in marine biology with specialization in aquaculture, diving, environmental sciences, and marine bioprospecting. Scientific Consulting: Extensive experience advising in natural molecules, functional supplements, agriculture, aquaculture, veterinary and human health, and nutraceuticals. Natural Molecules and Organic Chemistry: Expert in natural molecules and organic chemistry applied to the development of bioactive formulations for agriculture, veterinary medicine, and human health. Product Development: Skilled in creating new functional products based on scientifically validated natural ingredients with immunomodulatory, antioxidant, and hepatoprotective actions. Scientific Education and Product Management: Strong background in public speaking, professional training, and communication of scientific concepts to diverse audiences. Project and Field Management: Leadership in coordinating field studies and in vivo/in vitro testing with Catalysis products across different species and sectors. Business Development: Proven ability to identify new business opportunities and lead cross-disciplinary projects within the biotech and pharmaceutical sectors.