ReGeo ISSN: 2177-3246

BIOSTIMULANTS, PLANT GROWTH REGULATORS, AND MICROORGANISMS IN IRRIGATED AGRICULTURE OF THE MIDDLE SAN FRANCISCO VALLEY: A REVIEW BASED ON DISSERTATIONS FROM 2015 TO 2024

BIOESTIMULANTES FITORREGULADORES E MICROORGANISMOS NA AGRICULTURA IRRIGADA DO SUBMÉDIO DO VALE DO SÃO FRANCISCO: UMA REVISÃO BASEADA EM DISSERTAÇÕES DE 2015 A 2024

BIOESTIMULANTES, REGULADORES DEL CRECIMIENTO VEGETAL Y MICROORGANISMOS EN LA AGRICULTURA DE RIEGO DEL VALLE MEDIO DEL SAN FRANCISCO: UNA REVISIÓN BASADA EN TESIS DE 2015 A 2024

10.56238/revgeov17n1-093

Marcelo da Silva Martins[1], Susana Zapata Garcia[2], Laíres Sales Reis[3], Nicolly Quirino Barros Vieira[4], William Ralf Santos Costa[5], Wiltemberg de Brito Pereira[6], Jadson Miranda Oliveira[7], Roberval Oliveira da Silva[8]

ABSTRACT

The Middle São Francisco Valley is one of the main hubs of irrigated agriculture in Brazil, where technologies involving biostimulants, plant growth regulators, and microorganisms have been extensively studied with the aim of providing physiological support to crops, mitigating abiotic stresses, and promoting increases in yield and quality. This review aimed to analyze the published literature between 2015 and 2024, on the use of biostimulants, plant growth regulators, and microorganisms in irrigated agriculture in the São Francisco Valley, focusing on master's dissertations from the graduate programs in Irrigated Horticulture (PPGHI – UNEB), Plant Production (PPGPV – UNIVASF), and Agricultural Engineering (PPGEA – UNIVASF). The review was conducted using dissertations available in the universities' databases. For the selection of the works, specific filters were applied in each graduate program, considering the publication period (2015–2024) and the keywords (i) biostimulants, (ii) plant growth regulators, and (iii) microorganisms. Next, the dissertations

[1] Doctoral student in Agricultural Engineering. Universidade Federal do Recôncavo da Bahia (UFRB). Brazil. E-mail: marcelomartinsag1212@gmail.com Orcid: https://orcid.org/0000-0002-6933-4303
[2] Dr. in advanced agri-food research and development. Universidade Politécnica de Cartagena (UPCT). Spain. E-mail: susana.zapata@upct.es Orcid: https://orcid.org/0000-0003-0102-4314
[3] Master's student in Irrigated Horticulture. Universidade Estadual da Bahia (UNEB). Brazil. E-mail: proflaires@gmail.com Orcid: https://orcid.org/0000-0001-8536-277X
[4] Master's degree in Agricultural Engineering. Universidade Federal do Vale do São Francisco (UNIASF). Brazil. E-mail: nicollyqbv@gmail.com Orcid: https://orcid.org/0000-0002-9651-2443
[5] Master's degree in Agricultural Engineering. Universidade Federal do Vale do São Francisco (UNIASF). Brazil. E-mail: ralfw20@gmail.com Orcid: https://orcid.org/0000-0002-6609-0980
[6] Master's degree in Agricultural Engineering. Universidade Federal do Vale do São Francisco (UNIASF). Brazil. E-mail: berg4712wbp@gmail.com Orcid: https://orcid.org/0009-0002-9492-6930
[7] Doctoral student in Agricultural Engineering. Universidade Federal do Recôncavo da Bahia (UFRB). Brazil. E-mail: jacojmo@hotmail.com Orcid: https://orcid.org/0000-0002-6933-4303
[8] Doctoral student in Agricultural Engineering. Universidade Federal do Recôncavo da Bahia (UFRB). Brazil. E-mail: robervalos.eng@gmail.com Orcid:https://orcid.org/0009-0007-6793-8801

were read and classified by year and by program, along with the identification of the topics addressed and the synthesis of the main results, as well as the most studied crops. The PPGHI – UNEB had the highest number of studies involving microorganisms, while the PPGEA and PPGPV programs at UNIVASF produced more research related to biostimulants and plant growth regulators. During the analyzed period, the most studied/researched crops were mango, melon, and grape. All programs in partnership with EMBRAPA company carried out outstanding work on this topic, contributing significantly to the scientific and technological advancement of irrigated agriculture in the region.

Keywords: Abiotic Stress. Fruit Growing. Physiological Support. Agricultural Production. Brazilian Semi-Arid.

RESUMO

O Submédio do Vale do São Francisco constitui um dos principais polos de agricultura irrigada do Brasil, no qual tecnologias baseadas em bioestimulantes, fitorreguladores e microrganismos têm sido amplamente investigadas com o propósito de oferecer suporte fisiológico aos cultivos, mitigar estresses abióticos e promover incrementos na produção e na qualidade. O objetivo deste trabalho foi realizar uma revisão de literatura, referente ao período de 2015 a 2024, sobre o uso de bioestimulantes, fitorreguladores e microrganismos na agricultura irrigada do Vale do São Francisco, com base em dissertações de mestrado dos programas de pós-graduação em Horticultura Irrigada (PPGHI – UNEB), Produção Vegetal (PPGPV – UNIVASF) e Engenharia Agrícola (PPGEA – UNIVASF). A revisão foi conduzida a partir de dissertações disponíveis nas bases de dados das universidades. Para a seleção dos trabalhos, aplicaram-se filtros específicos em cada programa de pós-graduação, considerando o período de publicação (2015–2024) e os termos (i) bioestimulantes, (ii) fitorreguladores e (iii) microrganismos. Em seguida, procedeu-se à leitura e à quantificação das dissertações por ano e por programa, bem como à identificação dos temas abordados e à síntese dos principais resultados e aos cultivos mais estudados. O PPGHI – UNEB apresentou maior número de trabalhos envolvendo microrganismos, enquanto os programas PPGEA e PPGPV da UNIVASF produziram mais trabalhos relacionados a bioestimulantes e fitorreguladores. Para o período analisado, os cultivos mais estudados foram manga, melão e uvas. Todos os programas em parceria com EMBRAPA apresentaram excelentes trabalhos na temática, contribuindo significativamente para o avanço científico e tecnológico da agricultura irrigada na região.

Palavras-chave: Estresse Abiótico. Fruticultura. Suporte Fisiológico. Produção Agrícola. Semiárido Brasileiro.

RESUMEN

El Valle Medio del São Francisco constituye uno de los principales polos de agricultura de riego en Brasil, donde las tecnologías basadas en bioestimulantes, reguladores del crecimiento vegetal y microorganismos han sido ampliamente investigadas con el propósito de ofrecer soporte fisiológico a los cultivos, mitigar los estreses abióticos y promover incrementos en la producción y la calidad. El objetivo de este trabajo fue realizar una revisión de la literatura, referente al período de 2015 a 2024, sobre el uso de bioestimulantes, reguladores del crecimiento vegetal y microorganismos en la agricultura de riego del Valle del São Francisco, basada en disertaciones de maestría de los programas de posgrado en Horticultura de Riego (PPGHI – UNEB), Producción Vegetal (PPGPV – UNIVASF) e Ingeniería Agrícola (PPGEA – UNIVASF). La revisión se llevó a cabo a partir de tesis disponibles en las bases de datos de las universidades. Para la selección de los trabajos, se aplicaron filtros 2 específicos en cada programa de posgrado, considerando el período de publicación (2015–2024) y los términos (i) bioestimulantes, (ii) fitorreguladores

y (iii) microorganismos. A continuación, se procedió a la lectura y cuantificación de las disertaciones por año y por programa, junto con la identificación de los temas abordados y la síntesis de los principales resultados, además de los cultivos más estudiados. El PPGHI – UNEB presentó el mayor número de trabajos relacionados con microorganismos, mientras que los programas PPGEA y PPGPV de la UNIVASF produjeron más investigaciones relacionadas con bioestimulantes y fitorreguladores. Durante el período analizado, los cultivos más investigados fueron mango, melón y uva. Todos los programas en colaboración con EMBRAPA desarrollaron excelentes trabajos en la temática, contribuyendo significativamente al avance científico y tecnológico de la agricultura irrigada en la región.

Palabras clave: Estrés Abiótico. Fruticultura. Soporte Fisiológico. Producción Agrícola. Semiárido Brasileño.

1 INTRODUCTION

The Submiddle São Francisco Valley (SVSF) is one of the main irrigated agricultural hubs in Brazil, with emphasis on the production of irrigated fruits (Baiardi et al., 2023). The SVSF region comprises the municipalities of Petrolina, Lagoa Grande, Santa Maria da Boa Vista, Orocó, and Cabrobó in the state of Pernambuco, as well as Juazeiro, Casa Nova, Sobradinho, Curaçá, and Abaré in the state of Bahia, all of which are located within the Brazilian semi-arid region (Gondim et al., 2013). In this region, several irrigation methods are used; however, localized irrigation systems, represented mainly by drip and micro-sprinkler irrigation, predominate. According to Frizzone (2012), these methods are considered the most efficient in irrigated agriculture.

The adoption of localized irrigation is frequently associated with fertigation practices, allowing the application of different inputs throughout the crop cycle. In this context, the use of biostimulants that include plant extracts, seaweed extracts, humic and fulvic acids, biofertilizers; plant growth regulators, such as auxins, gibberellins, cytokinins, ethylene, paclobutrazol, salicylic acid, and ascorbic acid, as well as beneficial microorganisms - bacteria and fungi -, has intensified, as reported in previous studies (Melo, 2017; Aguiar, 2018; Lordêlo, 2019; Nascimento, 2019; Leal, 2023; Almeida, 2024). These products can be applied via fertigation, foliar spraying, or seed inoculation and are used as management strategies aimed at increasing productivity, improving fruit quality, and mitigating abiotic stresses, especially water deficit (Pais, 2016; Ferreira, 2019; Bezerra, 2020; Vargens, 2022; Martins et al., 2023; Silva, 2024).

The topic related to the use of biostimulants, plant growth regulators, and microorganisms has been widely discussed in the academic environment of the São Francisco Valley, particularly through master's dissertations developed in graduate programs focused on irrigated agriculture in the region. These include the Graduate Program in Irrigated Horticulture (PPGHI – UNEB), at the Juazeiro-BA 3 campus; the Graduate Program in Plant Production (PPGPV – UNIVASF), at the Petrolina-PE campus; and the Graduate Program in Agricultural Engineering (PPGEA – UNIVASF), at the Juazeiro-BA campus. These programs, often in partnership with Embrapa Semi-Arid, have significantly contributed to the development of technologies and strategies aimed at increasing production efficiency and sustainability of irrigated agricultural systems in the region.

In this context, the objective of this study was to conduct a literature review covering the period from 2015 to 2024 on the use of biostimulants, plant growth regulators, and microorganisms in irrigated agriculture in the São Francisco Valley, based on master's

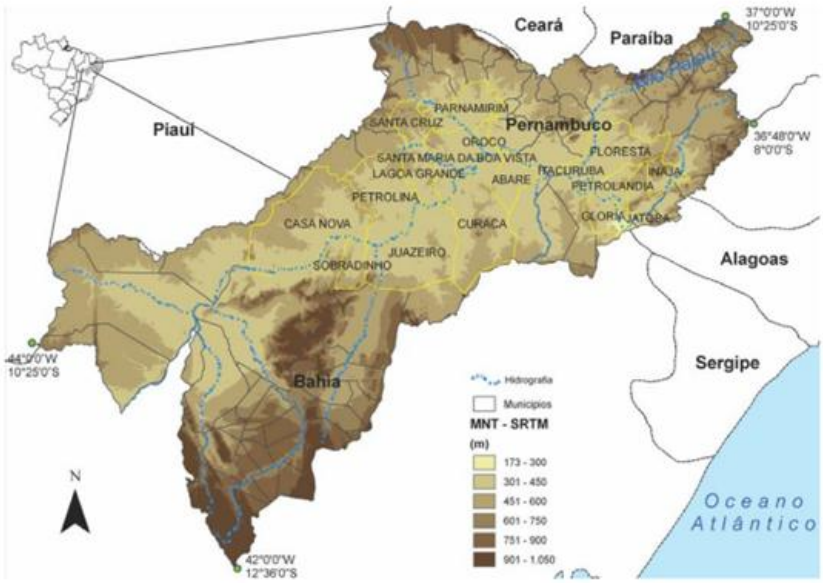
dissertations from the graduate programs in Irrigated Horticulture (PPGHI – UNEB), Plant Production (PPGPV – UNIVASF), and Agricultural Engineering (PPGEA – UNIVASF).

2 MATERIALS AND METHODS

The study consists of a literature review on the use of biostimulants, plant growth regulators, and microorganisms in irrigated agriculture in the Middle-Low São Francisco Valley, covering the period from 2015 to 2024. The region has an average altitude of 402 m and is located across municipalities in the states of Pernambuco and Bahia (Figure 1).

Figure 1

Location of the Middle-Low São Francisco Valley in the states of Pernambuco and Bahia



Source: Gondim et al., 2013.

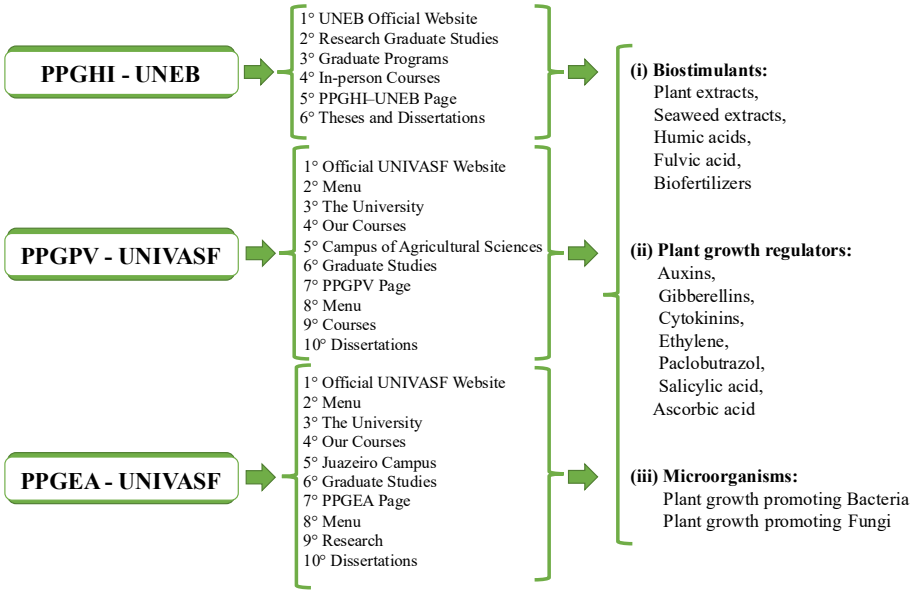
The research included theses from three stricto sensu graduate programs: Irrigated Horticulture (PPGHI – UNEB), at the Juazeiro-BA campus; Plant Production (PPGPV – UNIVASF), at the 4 Petrolina-PE campus; and Agricultural Engineering (PPGEA – UNIVASF), at the Juazeiro-BA campus. According to the Köppen classification, the Middle-Low São Francisco Valley falls under the BSh type, characterized as a semi-arid climate. The region has an average annual temperature of 26.0 °C and an average annual precipitation of approximately 500 mm, concentrated between January and April, with a relative humidity of around 66% (Leão et al., 2020).

The Middle-Low São Francisco Valley is one of the main hubs of irrigated agriculture in the country, and institutions such as UNEB and UNIVASF have been conducting relevant research on the application of biostimulants, plant growth regulators, and microorganisms

associated with agricultural production. For the construction of the review, data were obtained from the institutional repositories of the three aforementioned programs: Irrigated Horticulture (https://ppghi.uneb.br/b); Plant Production (https://producaovegetal.univasf.edu.br/); and Agricultural Engineering (https://portais.univasf.edu.br/ppgea). Accessed between (February 2, 2025 and December 28, 2025). The search considered terms related to the main groups of interest, applying specific filters for each set of terms, allowing the identification of theses that directly addressed the research topic: (i) Biostimulants: plant extracts, seaweed extracts, humic acids, fulvic acid, and biofertilizers; (ii) Plant Growth Regulators: auxins, gibberellins, cytokinins, ethylene, paclobutrazol, salicylic acid, and ascorbic acid; (iii) Microorganisms: plant growth-promoting bacteria and fungi. This process is summarized in the flowchart presented in Figure 2.

Figure 2

Flowchart of the thesis search process and categorization by biostimulants, plant growth regulators, and microorganisms in the graduate programs of UNEB and UNIVASF



Source: Prepared by the authors.

The initial selection the theses published were classified by year and program, along with the distribution of topics (biostimulants, plant growth regulators, and microorganisms) and the agricultural crops evaluated. Subsequently, the abstracts were read, followed by the full text, with the aim of identifying: the crop studied; the type of product applied (biostimulant, plant growth regulator, or microbial inoculant); the experimental conditions (field, nursery, or greenhouse); the application method (soil, foliar, or inoculation); and the main agronomic

effects observed.

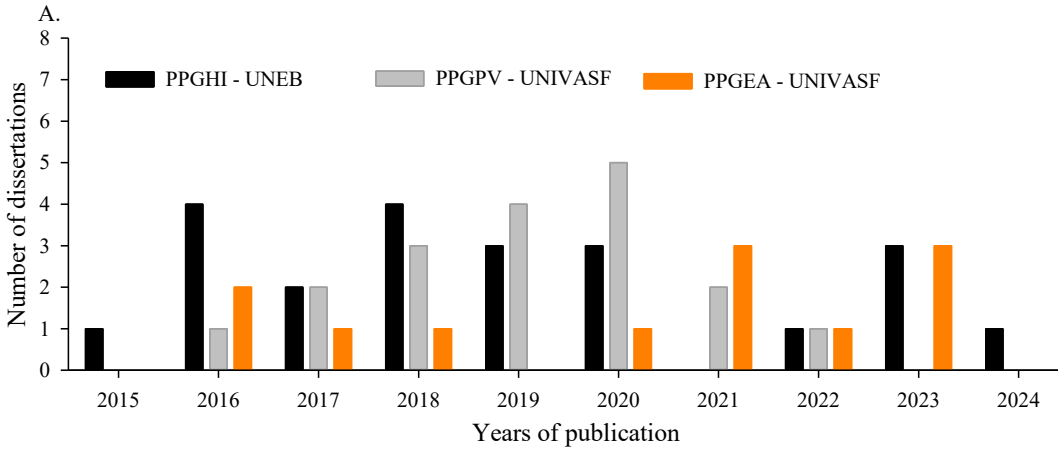
3 RESULTS AND DISCUSSION

The yearly distribution of the dissertations presented in Figure 3 shows that the PPGHI–UNEB exhibits greater regularity in the production of dissertations related to the use of biostimulants, plant growth regulators, and agricultural microorganisms between 2015 and 2023. An annual pattern of consistency is observed, with emphasis on 2016 and 2018, years in which the program reached four defended dissertations, in addition to its performance in 2023, with three dissertations. This continuity indicates that PPGHI–UNEB has played a key role in consolidating research involving bio-inputs in the region, especially in the early years of the historical series, acting as a driver for thematic maintenance and expansion.

PPGPV–UNIVASF showed a productivity pattern concentrated in specific periods (Figure 3). After an incipient output in 2016, the program reached its peak in 2019 and 2020, with four 6 dissertations each year. This interval represented the period of greatest contribution from PPGPV to the topic. From 2021 onward, a marked reduction in output was observed, with only one dissertation defended in that year and none in the subsequent years. This scenario may have been associated with the indirect effects of the COVID-19 pandemic, including difficulties in establishing field experiments and psychological impacts resulting from social isolation, as reported by Francisco et al. (2021) in a study involving with 200 students from different graduate programs at several Brazilian universities.

Figure 3

Number of dissertations published per year related to the use of biostimulants, plant growth regulators, and microorganisms in the graduate programs in Irrigated Horticulture (PPGHI–UNEB), Plant Production (PPGPV UNIVASF), and Agricultural Engineering (PPGEA–UNIVASF), from 2015 to 2024



Source: Prepared by the authors. Data from the graduate programs at UNEB and UNIVASF.

PPGEA–UNIVASF differs from the previous programs, showing later but consistent growth (Figure 3). After an initial phase of low output between 2016 and 2020, the program shows a significant increase in 2021 and 2023, with three dissertations in each year. This pattern indicates a growing interest within Agricultural Engineering in research involving bio-inputs, likely associated with the program's direct interface with irrigation technologies, water management, abiotic stress, and precision agriculture. É importante destacar a contribuição da EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), responsável por 30% das dissertações do PPGEA–UNIVASF avaliadas neste estudo, fornecendo infraestrutura experimental e suporte científico qualificado, com orientação e coorientação de seus pesquisadores.

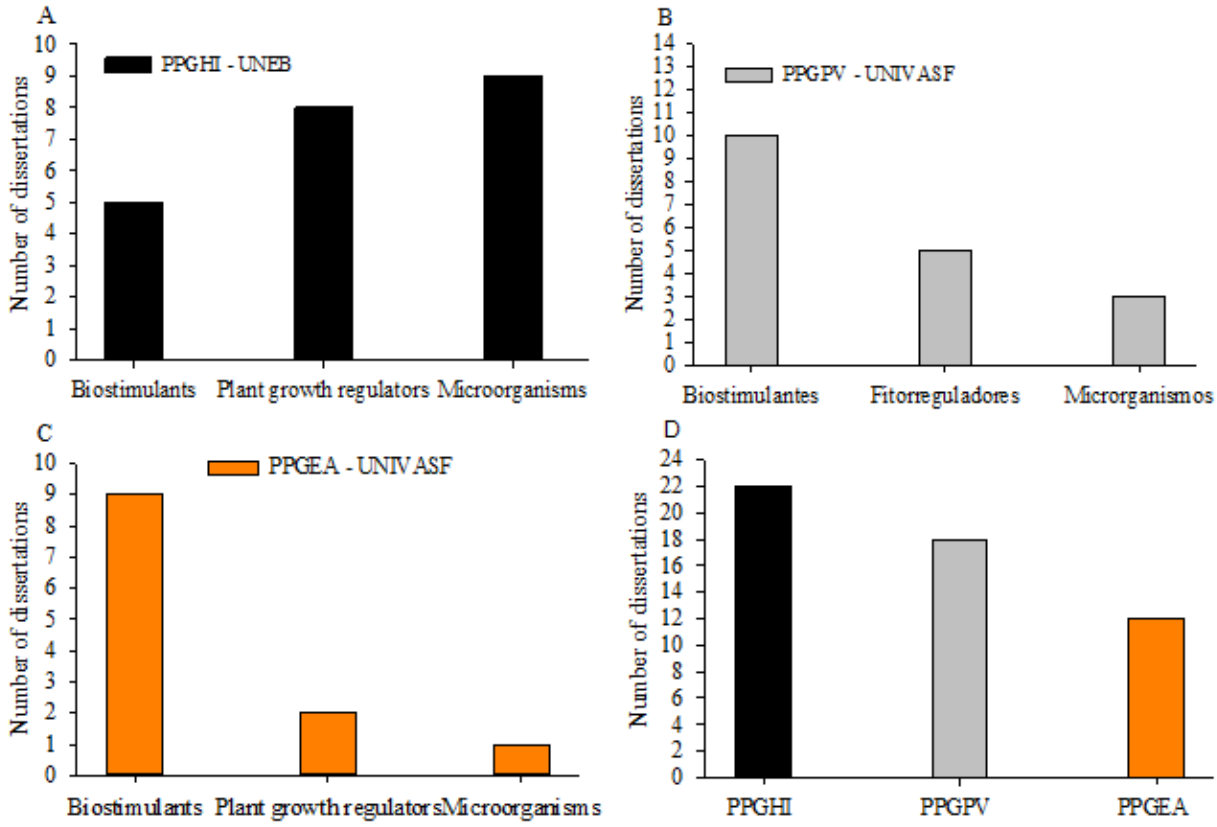
Regarding the number of studies according to the topics biostimulants, plant growth regulators, and microorganisms for PPGHI–UNEB (Figure 4A), there is a predominance of dissertations related to microorganisms, followed by plant growth regulators and biostimulants. This pattern demonstrates the strong connection of the program with research on agricultural microbiology applied to irrigation, particularly in strategic crops of the Sub-middle São Francisco Valley (SVSF). The balanced presence among the three categories illustrates the diversification of research lines and the program's ability to meet heterogeneous demands of the regional production sector.

In the PPGPV–UNIVASF (Figure 4B), a predominance of studies related to biostimulants is observed, due to the prominent role of the Research Group on Fruit Crops

in the São Francisco Valley (FRUTIVASF), which is recognized for conducting experiments in collaboration with companies from the mango production sector. According to De Fátima et al. (2024), the Northeast region of Brazil, represented by the São Francisco Valley, recorded a 15% increase in the area cultivated with mango between 2012 and 2021, according to data from the Brazilian Institute of Geography and Statistics (IBGE, 2024). In this context, the increase in the area cultivated with mango may have contributed to the high number of dissertations on this topic, since mango cultivation shows extensive use of plant growth regulators and biostimulants in the São Francisco Valley, as highlighted by Lobo (2018), Cunha (2019), Silva (2019), Carreiro (2020), Mudo (2020), and Martins et al. (2024).

Figure 4

Number of dissertations published related to the use of biostimulants, plant growth regulators, and microorganisms in the graduate programs: A. Irrigated Horticulture (PPGHI–UNEB), B. Plant Production (PPGPV UNIVASF), C. Agricultural Engineering (PPGEA–UNIVASF), and from 2015 to 2024



Source: Prepared by the authors. Data from the graduate programs at UNEB and UNIVASF.

In the PPGEA–UNIVASF, biostimulants accounted for the majority of research, with nine dissertations, followed by two on plant growth regulators and only one on microorganisms (Figure 4C). This profile highlighted the program's alignment with irrigation

management strategies based on the use of biostimulants to mitigate water deficit and increase the production of irrigated fruit and vegetable crops in the São Francisco Valley, as evidenced by the effects of humic and fulvic acids and seaweed extracts on mango trees (Martins, 2023; Araújo, 2022) and of nanoparticles and biofertilizers on watermelon and melon (Barros, 2023; Leite, 2021; Silva, 2016).

The overall synthesis shows that PPGHI–UNEB leads scientific production in the topic, with 22 dissertations, followed by PPGPV–UNIVASF with 18 and PPGEA–UNIVASF with 12 (Figure 4D). The observed differences reflect not only the level of program consolidation but also their scientific vocations, institutional collaboration capacity, and stability of research lines over time. The higher number of dissertations in PPGHI–UNEB may be associated with the fact that the program is older compared to the UNIVASF programs, possessing greater experience and organizational structure. This maturity supports a higher number of students and faculty advisors, enabling greater academic output.

The studies conducted between 2015 and 2024 by PPGHI–UNEB involving biostimulants focused mainly on grape, onion, watermelon, and melon crops, carried out under field conditions and in protected environments (Table 1). The application of polyamines to ‘Thompson Seedless’ grapes resulted in a significant increase in berry growth, while the marine calcareous seaweed extract Lithothamnium promoted yield gains in ‘BRS Vitória’ grapes (Loredelo, 2019; Aguiar, 2018). The use of biofertilizers favored vegetative development, production, and total yield of onion (Almeida, 2024), in addition to enhancing gas exchange and biochemical parameters in organically grown watermelon (Ramos, 2020). For ‘ old Mine’ melon, substrate-applied biostimulants did not produce statistically significant effects on the evaluated variables (Campos, 2018).

Regarding plant growth regulators, the dissertations from PPGHI–UNEB focused mainly on mango, grape, onion, and tomato crops. The application of cytokinins and gibberellins (BAP and A_3) to ‘Tommy Atkins’ mango increased fruit number and growth (Bezerra, 2020). The use of paclobutrazol, applied both via soil and fertigation, increased production and fruit number per plant in different mango cultivars, demonstrating efficiency in controlling vegetative growth and inducing flowering (Ferreira, 2019; Santos, 2017a; Souza, 2016a). In ‘BRS Vitória’ grapes, salicylic acid improved leaf development and biomass accumulation (Gomes, 2023). In the grape rootstocks ‘Paulsen 1103’ and ‘SO4’, the application of kinetin, gibberellic acid, and IBA significantly increased rooting and sprouting percentages (Moraes, 2018). In ‘Regent’ onion, plant growth regulators increased aerial and root biomass production (Fonseca, 2015), while in ‘ uba’ tomato, the application

of IBA, A_3, and kinetin enhanced stem growth and seedling root development (Oliveira, 2016), as it has been summarized in Table 1.

The dissertations from PPGHI–UNEB involving microorganisms focused mainly on cowpea (Leal, 2023; Nascimento, 2019; Sena, 2018; Souza, 2016b), melon (Melo, 2017), watermelon (Araújo, 2023), papaya (Vargens, 2022), and gerbera (Pais, 2016), conducted mostly under greenhouse and laboratory conditions (Table 1). The microorganisms evaluated included arbuscular mycorrhizal fungi (AMF) and bacteria belonging to the genera Bradyrhizobium and Bacillus, as well as isolates of Pseudomonas, Burkholderia, and Paraburkholderia, applied predominantly via seed inoculation or substrate incorporation, aiming to optimize the physiological performance of crops.

Table 1

Dissertations from the PPGHI–UNEB involving major crops, cultivation conditions, application methods, and the effects of biostimulants, plant growth regulators, and microorganisms from 2015 to 2024.

BIOSTIMULANTS					
Crop	**Description of the Biostimulants**	**Growing Conditions**	**Application Method**	**Effects and Plant Performance**	**References**
Grape ‘Thompson Seedless’	Polyamines	Field	Foliar	The mixture of putrescine, spermidine, and spermine promoted greater berry growth.	Lordêlo, (2019)
Grape ‘BRS Vitória’	Seaweed extract	Field	Fertigation and foliar	The doses of 18 and 35 kg ha^{-1} provided increases in yield per plant and, consequently, in productivity.	Aguiar, (2018)
Onion ‘IPA-11’	Biofertilizers	Field	Soil	Better vegetative development, yield, and total bulb productivity.	Almeida, (2024)
Watermelon	Biofertilizers	Field	ND	Gas exchange and biochemical parameters were increased at 30 and 45.	Ramos (2020)
Melon ‘Gold Mine’	Biostimulants	Greenhouse	Substrate	The biofertilizer did not show significant effects on	Campos, (2018)

				the evaluated characteristics.	
PLANT GROWTH REGULATORS					
Crop	**Description of Plant Growth Regulators**	**Growing Conditions**	**Application Method**	**Effects and Plant Performance**	**References**
Mango 'Tommy Atkins'	Cytokinins, and Gibberellins BAP and GA3	Field	Foliar	It promoted an increase in the number and growth of fruits per plant in mango.	Bezerra, (2020)
Mango 'Tommy Atkins'	Paclobutrazol	Field	Fertigation and soil	The increase in paclobutrazol doses applied via the irrigation system reduced gas exchange in mango.	Ferreira, (2019)
Mango 'Kent'	Paclobutrazol	Field	Soil	Applications promoted increases in panicle formation and in the number of fruits per plant.	Santos, (2017a)
Mango 'Palmer'	Paclobutrazol	Field	Fertigation and soil	Application via the irrigation system promoted a greater number of fruits per plant and higher productivity.	Souza, (2016a)
Grape 'BRS Vitória'	Salicylic acid	Greenhouse	Foliar	Salicylic acid doses promoted leaf development with a lower volume of water applied.	Gomes, (2023)
Grape - porta-enxerto 'Paulsen 1103' e 'SO4'	Kinetin, gibberellic acid, 4-indole-3-butyric acid (IBA)	Greenhouse	ND	The best results were observed in cuttings not treated with plant growth regulators (IBA), with a higher percentage of rooting and sprouting.	Moraes, (2018)
Onion 'Regent'	Cytokinin, Auxin, Gibberellin	Field	Foliar	Application of pyraclostrobin and boscalid provided a greater increase in biomass compared to the control treatments.	Fonseca, (2015)

Tomato 'Italiano Tyna'	IBA, GA3, kinetin	Laboratory	Seed	It favored an increase in stem diameter of seedlings and fresh root mass of seedlings	Oliveira, (2016)
MICROORGANISMS					
Crop	**Description of Microorganisms**	**Growing Conditions**	**Application Method**	**Effects and Plant Performance**	**References**
Yellow Melon	Arbuscular mycorrhizal fungi	Greenhouse	Inoculated on the seed	Mitigating the negative effect of water deficit.	Melo, (2017)
Cowpea	Mycorrhizal fungi and Rhizobium	Greenhouse	Inoculated on the seed	The addition of multiple microorganisms proved to be beneficial for the development of cowpea.	Leal, (2023)
Cowpea	Bradyrhizobium spp., BR 3262	Laboratory	Inoculated on the seed	The co-inoculation of Bradyrhizobium spp. isolates with BR3262 proved to be a beneficial practice for cowpea plants.	Nascimento, (2019)
Cowpea	Bradyrhizobium bacteria	Laboratory	Inoculated on the seed	It was possible to identify isolates with high symbiotic efficiency and the ability to tolerate 3% NaCl, acidic and alkaline pH.	Sena, (2018)
Cowpea	Bradyrhizobium spp.	Greenhouse	Inoculated on the seed	The inoculation of diazotrophic bacteria improved gas exchange in cowpea.	Souza, (2016b)
Watermelon	Bacillus spp.	Greenhouse	ND	The MIX of bacteria increased gas exchange at the 40% moisture level and maximized root length and volume.	Araújo, (2023)
Papaya	Mycorrhizal fungi	Greenhouse	Inoculated on the seed	The use of AMF promoted greater seedling development in both papaya hybrids.	Vargens, (2022)
Gerbera	Bacteria	Greenhouse	Substrate	Bacterial isolates had a beneficial effect on the development of the cultivar Essandre.	Pais, (2016)

Plants	Bacteria: Pseudomonas, Bacillus, Burkholderia, and Paraburkholderia	REVIEW	REVIEW	Among the main genera of P- and K-solubilizing bacteria, Pseudomonas, Bacillus, Burkholderia, and Paraburkholderia are the most frequently reported	Silva, (2024)

Source: Prepared by the authors. Data from the graduate program at UNEB. ND: the application method was not reported in the text.

the results demonstrate that the use of microorganisms constitutes an effective strategy to mitigate the effects of water deficit and salinity in the SVSF. AMF reduced the damage associated with water stress in melon (Melo, 2017) and improved growth and biomass accumulation in cowpea (Leal, 2023). Bradyrhizobium spp. (strain BR 3262) showed beneficial effects on nodulation and physiological performance of bean genotypes (Nascimento, 2019), and enhanced gas exchange parameters in common bean seedlings (Souza, 2016b). Additional studies identified bacterial isolates with high symbiotic efficiency and tolerance to salinity (3% NaCl), as well as resistance to acidic and alkaline pH (Sena, 2018). In watermelon, inoculation with Bacillus spp. increased root length and volume (Araújo, 2023), while in papaya, AMF promoted better initial seedling development (Vargens, 2022). These results, summarized in Table 1, reinforce the potential of microorganisms as biotechnological tools for agriculture in semiarid environments.

In PPGPV–UNIVASF, biostimulants were extensively investigated between 2015 and 2025 (Table 2), with a predominance of studies focused on mango, exploring different substances and their physiological, biochemical, and productive effects. In ‘Kent’ mango, foliar application of amino acids and seaweed extract significantly altered the physicochemical traits of fruits (Lobo, 2018), while melissyl alcohol increased the activity of the antioxidant enzymes superoxide dismutase (SOD), ascorbate peroxidase (APX), and catalase (CAT) (Sanches, 2020). In ‘Tommy Atkins’ mango, proline increased gas exchange rates and seaweed extract promoted greater floral uniformity (Cunha, 2019). In acerola, however, the application of humic substances did not significantly affect fruit quality attributes (Dias, 2017).

For ‘Palmer’ mango, the combination of humic substances and paclobutrazol was identified as a productive alternative (Silva, 2019), while the isolated application of humic substances via fertigation produced fruits with commercial standards compatible with export markets (Torres, 2019). In melon, protein application improved vegetative growth parameters (Rodrigues, 2018), while in guava, the use of biofertilizers significantly increased production (Santana, 2016). However, in acerola, humic substances did not influence fruit

quality attributes (Dias, 2017).

Plant growth regulators also produced consistent responses in studies conducted by PPGPV UNIVASF between 2015 and 2024 (Table 2), with a predominance of research applied to mango. In ‘Palmer’ mango, foliar application of gibberellins, au ins, naphthaleneacetic acid, and cytokinins reduced the incidence of stenospermocarpic fruits and increased the number of productive branches (Souza, 2019). In ‘Tommy Atkins’ mango, the use of fenpropimorph and paclobutrazol proved effective in inhibiting A_3 biosynthesis, resulting in increased transpiration and reserve accumulation (Carreiro, 2020).

Table 2

Dissertations from the PPGPV – UNIVASF involving major crops, cultivation conditions, application methods, and the effects of biostimulants and plant growth regulators from 2015 to 2024

BIOSTIMULANTS					
Crop	**Description of the Biostimulants**	**Growing Conditions**	**Application Method**	**Effects and Plant Performance**	**References**
Mango ‘Kent’	Aminoácidos livres e extrato de alga Lithothamnium	Field	Foliar	All physicochemical variables of the fruits were affected by the treatments, with different responses between growing seasons.	Lobo, (2018)
Mango ‘Tommy Atkins’	Extratos de algas e prolina	Field	Foliar	Proline was effective in increasing gas exchange rates; in contrast, plants treated with seaweed extract showed greater flowering uniformity.	Cunha, (2019)
Mango ‘Kent’	Melissil Álcool	Field	Foliar	The application positively enhanced total amino acid contents, free proline, total proteins, and the activity of the	Sanches, (2020)

				enzymes SOD, APX, and CAT.	
Mango 'Kent'	Ascophyllum nodosum e Prolina	Field	Soil and foliar	The isolated effects of proline and *A. nodosum* extract resulted in better nutritional status.	Moura, (2019)
Mango 'Palmer'	Subistancia húmicas, Paclobutrazol	Field	Soil	The use of humic substances associated with PBZ may represent an important alternative for mango production in the semi-arid region.	Silva, (2019)
Mango 'Palmer'	Subistancia humicas	Field	Fertigation	The fruits exhibited physicochemical characteristics that meet the quality standards established for international commercialization.	Torres (2019)
Mango 'Tommy Atkins'	Prolina e extrato de algas	Field	Foliar	The substances promoted increases in physiological, biochemical, and agronomic variables of the plants.	Cunha, (2019)
Melon	Proteinas	Greenhouse	Soil and foliar	Growth parameters of melon plants and β-glucosidase activity were significantly higher in fertilized treatments.	Rodrigues, (2018)
Guava	Biofertilizantes	Field	Fertigation	Fertigation with biofertilizer at 2.5% increased guava fruit yield by 12.61 kg plant^{-1}.	Santana, (2016)

Acerola	Subistancia humicas	Field	Fertigation	The application of humic substances and nitrogen doses did not alter the fruit quality of acerola.	Dias, (2017)
PLANT GROWTH REGULATORS					
Crop	**Description of Plant Growth Regulators**	**Growing Conditions**	**Application Method**	**Effects and Plant Performance**	**References**
Mango 'Palmer'	Giberelina; Auxina; Naftalenoacético; Citocininas	Field	Foliar	Cytokinin reduced the incidence of stenospermocarpic fruits and promoted higher means for the number of productive branches.	Souza, (2019)
Mango 'Tommy Atkins'	Fenpropimorfe, Paclobutrazol	Field	Soil	Fenpropimorph is efficient in inhibiting GA_3 biosynthesis, promoting increased transpiration and reserve accumulation.	Carreiro, (2020)
Mango 'Keitt'	AG3	Field	Foliar	Physical fruit characteristics, including estimated volume, fruit mass, and seed yield, were influenced by the interaction between factors (fertilization × gibberellin).	Mudo, (2020)
Onion	citocinina, giberelina, auxina	Field	Soil	Soil chemical and microbiological properties were influenced after the application.	Silva, (2020)
Rosa	citocinina, giberelina, auxina	Sombreado	Foliar	Plant growth regulators promoted greater increases in	Silva, (2018)

				rose growth and positively affected gas exchange.	
MICROORGANISMS					
Crop	**Description of Microorganisms**	**Growing Conditions**	**Application Method**	**Effects and Plant Performance**	**References**
Mango 'Keitt'	Rhodopseudomonas palustris	Field	Fertigation	*Rhodopseudomonas palustris* is a promising option for the cultivation of 'Keitt' mango irrigated under semi-arid conditions.	Lino, (2020)
Melon	Micorrízicos arbusculares, auxina e citocinina	Field	Fertigation	Reducing irrigation depth in melon cultivation does not affect sporulation but alters composition and reduces the diversity of AMF.	Silva, (2017)
Rhaphiodon echinus e *Mesosphaerum suaveolens*.	Fungos micorrízicos arbusculares (FMA)	Greenhouse	Inoculaçao	Native AMF produced with *S. uniflora* provide benefits to the development of *Rhaphiodon echinus* and *Mesosphaerum suaveolens* plants.	Medeiros, (2021)

Source: Prepared by the authors. Data from the graduate program at UNIVASF.

For the 'Keitt' cultivar, e ogenous A_3 application positively influenced fruit mass, volume, and seed yield (Mudo, 2020). In onion, the application of cytokinin, gibberellin, and auxin promoted relevant changes in soil chemical and microbiological properties (Silva, 2020).

Regarding microorganisms, only two dissertations were identified in PPGPV–UNIVASF (Table 2). In melon, the association between arbuscular mycorrhizal fungi (AMF), auxins, and cytokinins applied via fertigation demonstrated that reduced irrigation depth did not compromise AMF sporulation, although it altered composition and reduced AMF diversity (Silva, 2017). In Rhaphiodon echinus and Mesosphaerum suaveolens, inoculation with

native AMF enhanced plant development, reinforcing the potential of these microorganisms for semiarid conditions (Medeiros, 2021). For the 'Keitt' cultivar, the application of Rhodopseudomonas palustris proved agronomically efficient, indicating biotechnological potential for productive management (Lino, 2020).

The dissertations from PPGEA–UNIVASF, produced between 2015 and 2025, highlight the broad use of biostimulants, plant growth regulators, and microorganisms in fruit and vegetable crops grown in semiarid environments (Table 3). Biostimulants showed expressive responses in several crops, especially mango, melon, and cucurbits. In 'Tommy Atkins' mango, the application of fulvic and humic acids via fertigation increased leaf levels of amino acids, proteins, and total soluble carbohydrates (Martins, 2023). In 'Palmer' mango, the use of seaweed e tract combined with humic substances and different hormonal classes (cytokinins, auxins, and gibberellins) increased biochemical levels in leaves (Araújo, 2022).

In 'BRS Isis' grapes, the foliar application of humic substances, bacteria, and biocompost positively influenced shoot length and number of leaves (Barros, 2020). In yellow melon, carbon nanoparticles applied via foliar application and fertigation positively affected physiological and biochemical traits (Barros, 2023), while the use of biofertilizers increased chlorophyll a and b, photosynthesis, stomatal conductance, and productivity (Leite, 2021). Similar results were observed in watermelon, where intermediate doses of biofertilizers yielded the best photosynthesis, stomatal conductance, and transpiration values (Silva, 2016).

In bell pepper, the application of humic substances combined with reduced mineral fertilization resulted in significant increases in total yield and average fruit weight (Souza, 2021). In yam, the application of free amino acids and Ascophyllum nodosum was identified as a physiologically efficient and promising strategy for the crop (Santos, 2017b). Similarly, in passion fruit, the use of humic substances proved to be a viable alternative for seedling production in organic fertilization systems, promoting better initial plant performance (Santos, 2021) (Table 3).

Table 3

Dissertations from the PPGEA – UNIVASF involving major crops, cultivation conditions, application methods, and the effects of biostimulants, plant growth regulators, and microorganisms from 2015 to 2024

BIOSTIMULANTS					
Crop	**Description of the Biostimulants**	**Growing Conditions**	**Application Method**	**Effects and Plant Performance**	**References**
Mango 'Tommy Atkins'	Ácidos fulvico e ácido húmicos	Field	Fertigation	The application of biostimulants resulted in increased leaf contents of amino acids, proteins, and total soluble carbohydrates.	Martins, (2023)
Mango 'Palmer'	Extrato de algas marinhas; Subistacia humicas citoquininas, auxinas e giberelinas,	Field	Fertigation	It promoted increases in the biochemical contents of mango leaves.	Araújo, (2022)
Grape 'BRS Isis'	Subistacia húmicas, biocomposto	Field	Foliar	The biocompost positively influenced shoot length and number of leaves.	Barros (2020)
Melon	Nanoparticulado de carbono	Field	Foliar and Fertigation	The biostimulant used positively affected the physiological and biochemical characteristics of melon plants.	Barros, (2023)

Melon	Biofertilizantes	Field and Greenhouse	Fertigation	The biofertilizer promoted increases in chlorophyll a and b contents, photosynthesis, stomatal conductance, as well as higher productivity.	Leite, (2021)
Watermelon	Biofertilizantes	Field	Foliar and Fertigation	Intermediate doses of the biofertilizer provided the highest values of photosynthesis, stomatal conductance, and transpiration.	Silva, (2016)
Bell pepper	Subistacia humicas	Greenhouse	Soil	The lowest fertilization rate resulted in higher total yield and average fruit weight.	Souza, (2021)
Yam	Aminoacidos livres; Ascophyllum nodosum	Field	Foliar	The 100 mL dose showed the highest mean fresh tuber weight (1.677 kg).	Santos, (2017b)
Passion fruit	Subistacia humicas	Greenhouse	Soil	It proved to be a good option for seedling production under organic fertilization.	Santos, (2021)
PLANT GROWTH REGULATORS					

Crop	Description of Plant Growth Regulators	Growing Conditions	Application Method	Effects and Plant Performance	References
Melon	Citoquininas, auxinas e giberelinas	Field	ND	The 4.8 L ha^{-1} dose increased pulp firmness in both growing seasons.	Reis, (2018)
Melon	Auxina e citocinina	Field	ND	The highest values of firmness and total soluble solids were observed under the lowest irrigation depth.	Ferreira, (2016)
MICROORGANISMS					
Crop	**Description of Microorganisms**	**Growing Conditions**	**Application Method**	**Effects and Plant Performance**	**References**
Zea mays	Bacterias remineralizadora	Greenhouse	Soil	Potential benefits for conservation agriculture were observed through the use of remineralizers.	Sydne, 2023

Source: Prepared by the authors. Data from the graduate program at UNIVASF. ND: the application method was not reported in the text.

Plant growth regulators also directly influenced fruit quality, especially in melon, the application of cytokinins, auxins, and gibberellins increased pulp firmness in two consecutive growing cycles (Reis, 2018). Complementarily, the application of auxin and cytokinin combined with a reduced irrigation depth resulted in higher pulp firmness and total soluble solids, demonstrating a beneficial interaction between plant growth regulators and water management (Ferreira, 2016). Regarding the use of microorganisms, in maize cultivated under greenhouse conditions, inoculation with remineralizing bacteria was considered a promising strategy for improving the crop's nutritional and physiological conditions, reinforcing their potential for the agricultural systems of the SVSF (Sydne, 2023) (Table 3).

The distribution of crops studied in the works involving biostimulants, plant growth regulators, and microorganisms has been analyzed in figure 5. Refers to PPGHI–UNEB, showing a evenly distributed range of crops. Mango, grape, cowpea, onion, and melon, exhibit similar proportions (between 9% and 18%), characterizing a broad research scope consistent with the strategic importance of these crops for irrigated horticulture in Northeastern Brazil Figure 5A.

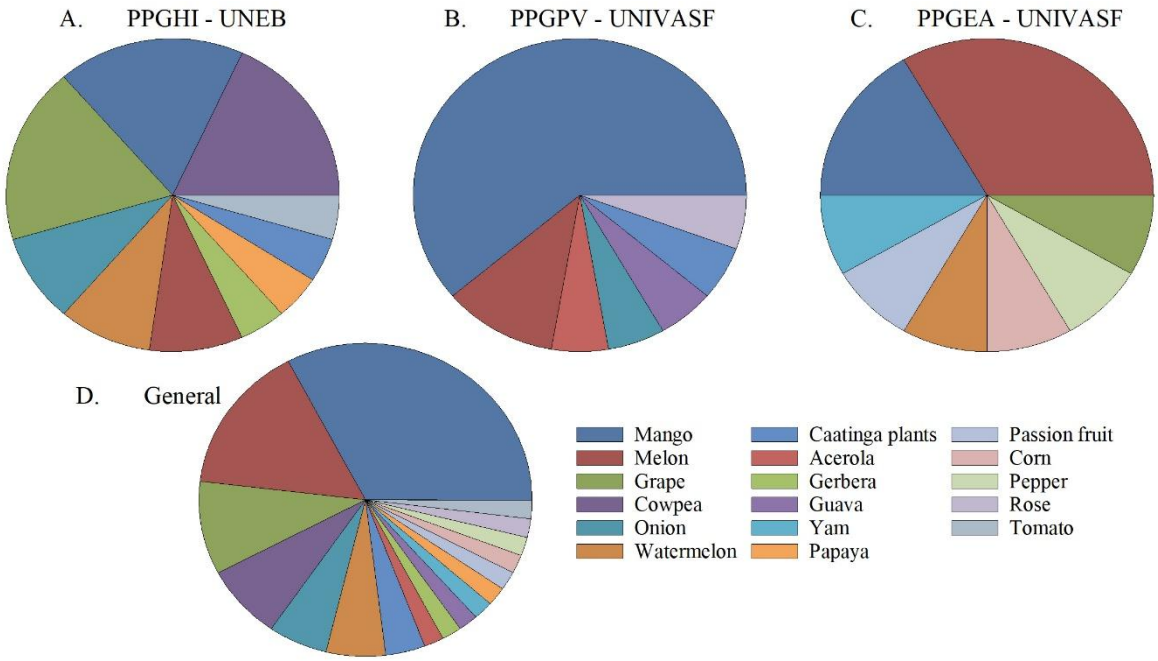
In contrast, the Graduate Program in Plant Production (PPGPV–UNIVASF) (Figure 5B) shows strong thematic concentration, with an absolute predominance of mango (61% of studies), while pear and guava appear sporadically. This scenario indicates a clear programmatic vocation toward mango cultivation, aligned with the socioeconomic importance of this production chain in the São Francisco Valley. Although it demonstrates scientific specialization, it also suggests lower thematic diversification compared to the other evaluated programs.

In the Graduate Program in Agricultural Engineering (PPGEA–UNIVASF), an intermediate pattern between diversity and specialization is observed (Figure 5C). Although melon and mango show the highest percentages (33% and 17%, respectively), other crops such as grape, passion fruit, maize, yam, and bell pepper each represent 8.33%, forming a more balanced distribution. This behaviour aligns with the multidisciplinary nature of Agricultural Engineering, which integrates aspects of water management, ecophysiology, productivity, and the development of technologies aimed at intensive cropping systems in semiarid regions.

The overall synthesis of the three programs (Figure 5D) shows that mango stands out as the most studied crop (33%), followed by melon (15%), grape (10%), and cowpea (8%). This predominance reinforces the importance of irrigated fruit crops in the semiarid region, which are strongly linked to the production chains of the São Francisco Valley. The remaining species appear in smaller proportions, indicating that although there is diversity in the studies, the economically most relevant crops of irrigated fruit production continue to be prioritized.

Figure 5

Percentage of the main crops studied in dissertations related to the use of biostimulants, plant growth regulators, and microorganisms in the graduate programs: A. Irrigated Horticulture (PPGHI–UNEB), B. Plant Production (PPGPV UNIVASF), and C. Agricultural Engineering (PPGEA–UNIVASF), from 2015 to 2024



Source: Prepared by the authors. Data from the graduate programs at UNEB and UNIVASF.

Overall, it is observed that biostimulants, plant growth regulators, and microorganisms have been predominantly applied to high-value crops, reinforcing the search for biotechnological solutions capable of enhancing productivity, physiological efficiency, and postharvest quality.

4 CONCLUSIONS

The PPGHI – UNEB presented the highest number of studies involving microorganisms, especially plant growth-promoting bacteria and fungi, in addition to the plant growth regulator paclobutrazol. The most studied crops were bean, mango, and grape, each representing 18% of the theses analyzed over the ten-year period.

The PPGEA and PPGPV programs at UNIVASF concentrated most of the research related to biostimulants and plant growth regulators, with humic substances, paclobutrazol, and seaweed extracts standing out. In the PPGEA program, 33% of the studies were directed at melon cultivation, while in the PPGPV program, 61% of the research involved mango cultivation.

Between 2015 and 2024, the graduate programs in Irrigated Horticulture (PPGHI –

UNEB), Plant Production (PPGPV – UNIVASF), and Agricultural Engineering (PPGEA – UNIVASF), in partnership with EMBRAPA Semiárido, developed relevant contributions on the use of biostimulants, plant growth regulators, and microorganisms in irrigated fruit production in the São Francisco Valley, strengthening the region's technological advancement and promoting increased productivity and quality of fruits, vegetables, and legumes.

REFERENCES

Almeida, A. C. dos S. (2023). Desempenho agronômico de cebola cultivada em dois períodos de produção sob diferentes concentrações de biofertilizante (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://ppghi.uneb.br/wp-content/uploads/2025/02/1.1.Dissertacao-Cecilia_corrigido-com-ficha.pdf

Aguiar, C. A. da C. de. (2018). Extrato de alga marinha calcária (Lithothamnium) no desenvolvimento, produção e qualidade pós-colheita de frutos da videira "BRS Vitória" (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp-content/uploads/2021/01/CARLOS-ANTONIO-DA-COSTA-DE AGUIAR.pdf

Araújo, M. G. de. (2023). Inoculação de Bacillus spp. em sementes de melancieira como estratégia para mitigar os efeitos do déficit hídrico (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://ppghi.uneb.br/wp content/uploads/2025/02/Dissertacao-Final_Mycaella-1.pdf Pós-Graduação

Araújo, L. R. da S. (2022). Aplicação de bioestimulantes e doses em mangueira cv. 'Palmer' no Submédio do Vale do São Francisco (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de em Engenharia Agrícola – PPGEA, Campus Juazeiro.https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes1/arquivos/DISSERT LUCASARAJO22122 022.pdf

Baiardi, A., & Ribeiro, M. C. M. (2023). Eficiência da gestão da agricultura irrigada no Vale do São Francisco: uma análise comparativa no polo regional Petrolina-Juazeiro. Colóquio-Revista do desenvolvimento regional, 20(3, jul./set.), 28-51. https://doi.org/10.26767/coloquio.v20i3,%20jul./set..2788

Barros, E. S. C. (2020). Produção de biocomposto proveniente da vinicultura e aplicação no desenvolvimento de mudas de videira (Vitis vinifera L.) (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Engenharia Agrícola – PPGEA, Campus Juazeiro.https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes1/arquivos/EDUARD OSOUZACOSTABA RROS.pdf

Barros, N. Q. (2023). Aplicação do bioestimulante arbolina no cultivo de melão amarelo sob diferentes manejos de irrigação (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Engenharia Agrícola – PPGEA, Campus Juazeiro. https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes1/arquivos/DISSERTAO_NIC

OLLYQUIRINOBAR ROS_PDF.pdf

Bezerra, J. B. N. (2020). Fitorreguladores no crescimento, qualidade e produção de frutos de mangueira 'Tommy Atkins' (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, content/uploads/2021/01/JOAO-BOSCO-NUNES-BEZERRA.pdf BA. https://www.ppghi.uneb.br/wp

Carreiro, D. de A. (2020). Fenpropimorfe no manejo da floração em mangueira 'Tommy Atkins' no semiárido (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em 19 Produção Vegetal – PPGPV, Campus Petrolina, content/uploads/2022/05/Daniel-de-Almeida-Carreiro_2020.pdf PE. https://www.frutvasf.org/wp

Campos, L. D. A. (2019). Efeito do déficit hídrico controlado (RDI) e uso de bioestimulante nas características de crescimento, bioquímicas e de trocas gasosas do meloeiro (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp-content/uploads/2021/01/LUAN-DAVID-ALCANTARA-CAMPOS.pdf

Cunha, J. G. da. (2019). Fornecimento de prolina e extrato de algas como atenuante do estresse abiótico em mangueira 'Tommy Atkins' cultivada no semiárido (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://www.frutvasf.org/wp-content/uploads/2022/06/Jeilton-Gomes-da-Cunha_2019.pdf

Dias, D. do N. (2017). Substâncias húmicas na fertirrigação nitrogenada da aceroleira (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://producaovegetal.univasf.edu.br/Arquivos/dayane.pdf

Fátima, V. M. (2024). FRUTICULTURA (MANGA): v. 9 n. 371, dezembro, 2024. Caderno Setorial ETENE, . Francisco, L. P. L., Fernandes, C. B., Vio, N. L., de Oliveira Pascoal, I., Feijó, M. R., & Camargo, M. L. (2021). Impactos da pandemia no estudo e dinâmica de vida de universitários brasileiros. Conjecturas, 21(4), 376-395. DOI: 10.53660/CONJ-196-614

Ferreira, K. M. (2019). Fisiologia, produção e qualidades de fruto da mangueira "Tommy Atkins" cultivada sob diferentes formas de aplicação do paclobutrazol (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp-content/uploads/2019/04/Kalline-Mendes-Ferreira.pdf

Ferreira, P. P. B. (2016). Resposta do melão amarelo à interação lâmina de irrigação e bioestimulante (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Engenharia Agrícola – PPGEA, Campus Juazeiro.https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes 1/arquivos/PedroPauloBezerraFerreira.pdf

Fonseca, R. A. (2015). Reguladores vegetais e fungicidas com efeitos fisiológicos no desenvolvimento de plantas de cebola (Dissertação de mestrado, Universidade do

Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp content/uploads/2021/01/Rodrigo-Almeida-Fonseca.pdf

Gondim, R. et al. (2013). Projeções de demanda hídrica para irrigação do meloeiro no Submédio São Francisco sob cenários de mudanças climáticas. Recuperado em 23 novembro 2025, de https://www.sidalc.net/search/Record/dig-infoteca-e-doc-972686/Description

Gomes, I. P. F. de A. (2023). Ácido salicílico em mudas de videira cultivar BRS Vitória sob deficiência hídrica (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://ppghi.uneb.br/wp-content/uploads/2025/02/Dissertacao Mestrado-Iana-.pdf IBGE - INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Produção Agrícola Municipal. Rio de Janeiro, 2024. Disponível em: . Acesso em: 11 de nov. de 2024 20 Vegetal

Lobo, J. T. (2018). Bioestimulante no cultivo da mangueira cv. Kent no submédio do Vale do São Francisco (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção – PPGPV, Campus content/uploads/2022/06/Jackson-Teixeira-Lobo_2018.pdf Petrolina, PE. https://www.frutvasf.org/wp

Lordêlo, C. M. M. (2019). Poliaminas em videira 'Thompson Seedless' (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp-content/uploads/2019/04/DISSERTACAO-CLAUDIO.pdf

Leite, E. W. S. (2021). Uso eficiente de biofertilizante no cultivo de variedades de melão no Submédio do Vale do São Francisco (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós Graduação em Engenharia Agrícola – PPGEA, Campus Juazeiro.https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes1/arquivos/DISSERTACAOMELAOEmers on.pdf

Leal, V. de C. (2023). Feijão-caupi associado a fungos micorrízicos arbusculares e rizóbio, cultivado sob condição salina (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, content/uploads/2021/01/VERONICA-DE-CASTRO-LEAL.pdf BA. https://www.ppghi.uneb.br/wp

Lino, J. de O. S. (2020). Rhodopseudomonas palustris como bioestimulantes em mangueira 'Keitt' no semiárido (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://www.frutvasf.org/wp content/uploads/2022/05/Jaynne-de-Oliveira-Siqueira-Lino_2020.pdf

Moraes, J. P. S. de. (2018). Reguladores vegetais e fungicidas com efeitos fisiológicos no desenvolvimento de porta-enxertos de videira (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp content/uploads/2021/01/Jadson-Moraes.pdf

Melo, J. M. M. (2017). Híbridos de meloeiro inoculados com fungos micorrízicos arbusculares e submetidos ao estresse hídrico no Vale do Submédio do São Francisco (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp-content/uploads/2021/01/JULIANA-MARIA-MEDRADO-DE-MELO.pdf

Medeiros, A. S. de. (2021). Produção de inoculante micorrízico e aplicação em plantas usadas na recuperação de áreas degradadas (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – https://producaovegetal.univasf.edu.br/Arquivos/adler.pdf PPGPV, Campus Petrolina, PE.

Mudo, L. E. D. (2020). Estratégias para fixação e desenvolvimento de frutos em mangueira cv. Keitt cultivada no semiárido (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://www.frutvasf.org/wp content/uploads/2022/05/Laiane-Eugenia-Delmondes-Mudo_2020.pdf

Moura, F. M. de. (2019). Prolina e extrato de Ascophyllum nodosum no estado nutricional da mangueira ‘Kent’ (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://www.frutvasf.org/wp content/uploads/2022/05/Franciele-Miranda-de-Moura_2019.pdf

Martins, M. da S. (2023). Fisiologia e produtividade da mangueira 'Tommy Atkins' com aplicação de bioestimulantes à base de substâncias húmicas no semiárido brasileiro (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Engenharia Agrícola – PPGEA, Campus Juazeirohttps://portais.univasf.edu.br/ppgea/pesquisa/publicacoes1/arquivos/PTBRMarceloMartinsDissertaofi nal.pdf BA.

Nascimento, T. R. do. (2019). Coinoculação de Bradyrhizobium spp. em feijão-caupi (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, https://www.ppghi.uneb.br/wp-content/uploads/2021/01/TAILANE-RIBEIRO-DO NASCIMENTO.pdf

Oliveira, Z. V. S. R. (2020). Aplicação de biofertilizante no cultivo orgânico de melancia no semiárido brasileiro (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp content/uploads/2021/01/ZEZIA-VERONICA-SILVA-RAMOS-OLIVEIRA.pdf

Oliveira, C. K. dos S. (2016). Reguladores vegetais e nutrientes no desenvolvimento do tomateiro (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp-content/uploads/2021/01/Carmem-Kely-dos-Santos Oliveira.pdf

Pais, A. K. L. (2016). Micropropagação de Gérberas e avaliação de bactérias promotoras de crescimento (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp-content/uploads/2021/01/Ana Karolina-Leite-Pais.pdf

Rouphael, Y., & Colla, G. (2020). Editorial: Biostimulants in agriculture. Frontiers in Plant Science, 11, 40.

Reis, D. S. (2018). Efeito de lâminas de irrigação e bioestimulante na fisiologia e produção de variedades de melão (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Engenharia Agrícola – PPGEA, Campus Juazeiro https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes 1/arquivos/daise-souza-reis.pdf

Rodrigues, M. E. B. (2018). Bioestimulante em cultivo de meloeiro: Efeitos sobre parâmetros biométricos e biomassa microbiana do solo (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://producaovegetal.univasf.edu.br/Arquivos/eugenia.pdf Pós-Graduação

Santos, I. H. (2017b). Adubação potássica associada a fósforo, micronutrientes e bioestimulante no cultivo de Dioscorea cayennensis (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de em Produção Vegetal – PPGPV, Campus https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes-1/arquivos/iuri-honorio-santos.pdf Petrolina, PE.

Santos, E. H. F. (2021). Compostos orgânicos e a dinâmica do crescimento vegetativo do maracujazeiro amarelo (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós Graduação em Engenharia Agrícola – PPGEA, Campus Juazeiro.https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes1/arquivos/dissertaodemestradoEricaHeloise FreitasSantos1.pdf

Santos, S. A. dos. (2017a). Produção e qualidade de frutos da mangueira “Kent” com o uso de paclobutrazol (PBZ) (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus content/uploads/2021/01/Saulo-Alves-dos-Santos.pdf Juazeiro, BA. https://www.ppghi.uneb.br/wp

Silva, M. V. T. da. (2016). Doses e formas de aplicação de biofertilizante no cultivo da melancia sem semente (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em 22 Engenharia Agrícola – PPGEA, Campus Juazeiro.https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes 1/arquivos/max-venicius-teixeira-da-silva.pdf

Silva, T. S. da. (2020). Aplicação de bioestimulantes em cultivo fertirrigado de cebola (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://producaovegetal.univasf.edu.br/Arquivos/tamiressoares.pdf

Silva, T. D. F. da. (2017). Fungos micorrízicos arbusculares associados a lâminas de irrigação e bioestimulante no meloeiro (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://producaovegetal.univasf.edu.br/Arquivos/tamires.pdf

Silva, T. S. da. (2022). Substâncias húmicas na nutrição, produtividade, qualidade de frutos e na absorção de paclobutrazol em mangueira cultivada em solos frágeis da região semiárida brasileira. (Dissertação de mestrado, Universidade Federal do Vale do São

Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://producaovegetal.univasf.edu.br/Arquivos/talisonsilva.pdf Pós-Graduação

Silva, M. L. N. da. (2018). Fisiologia do crescimento e metabolismo de rosa de corte sob aplicação de produtos de efeitos fisiológicos. (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de em Produção Vegetal https://producaovegetal.univasf.edu.br/Arquivos/lourdes.pdf – PPGPV, Campus Petrolina, PE.

Silva, E. P. (2024). Bactérias solubilizadoras de fósforo e potássio isoladas da Caatinga na promoção de crescimento vegetal (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus content/uploads/2025/02/Dissertacao-Versao-final-Edilania.pdf Juazeiro, BA. https://ppghi.uneb.br/wp

Souza, L. S. B. de. (2016b). Desenvolvimento vegetativo e respostas fisiológicas de feijão-caupi inoculado sob diferentes lâminas de irrigação (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp content/uploads/2021/01/LAYANE-SILVA-BARBOSA-DE-SOUZA.pdf

Souza, R. M. A. (2021). Demanda hídrica e aspectos produtivos do pimentão submetido a diferentes níveis de adubação orgânica e lâminas de irrigação em cultivo protegido (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Engenharia Agrícola – PPGEA, Campus Juazeiro. https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes1/arquivos/DISSERTAOFINALRUANNAMASOUZ A.pdf

Souza, V. de. (2019). Estudo fenológico da morte do embrião e estratégias para mitigar a ocorrência de estenoespermocarpia em frutos de manga 'Palmer' (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://www.frutvasf.org/wp-content/uploads/2022/06/Vanuza-de-Souza_2019.pdf

Souza, M. A. de. (2016a). Caracterização fisiológica e produção da mangueira em função da aplicação de paclobutrazol via sistema de irrigação (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp content/uploads/2021/01/MOISES-ALVES-DE-SOUZA.pdf

Sanches, L. G. (2020). Mitigação de estresse abiótico com aplicação exógena de melissil álcool em mangueira cv. Kent cultivada no semiárido (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://www.frutvasf.org/wp-content/uploads/2022/05/Luciana-Guimaraes-Sanches_2020.pdf

Sydne, B. (2023). Uso de remineralizadores associados a bactérias solubilizadoras de nutrientes como condicionadores do solo para a cultura do milho (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Engenharia Agrícola – PPGEA, Campus Juazeiro. https://portais.univasf.edu.br/ppgea/pesquisa/publicacoes-1/arquivos/DicertacoBanelSYDNE.pdf

Santana, E. A. (2016). Biofertilizante bovino e nitrogênio via fertirrigação na cultura da goiabeira Paluma no Vale do São Francisco (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://www.frutvasf.org/wp content/uploads/2022/06/Elisson-Alves-Santana_2016.pdf

Sena, P. T. S. (2018). Caracterização polifásica de bactérias isoladas de nódulos de feijão-caupi em solos sob diferentes usos agrícolas do semiárido baiano (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://www.ppghi.uneb.br/wp-content/uploads/2021/01/Pamella-versao-final-1.pdf

Torres, A. P. (2019). Ácidos orgânicos na nutrição, produtividade e qualidade de frutos de mangueira cv. Palmer no Vale do São Francisco (Dissertação de mestrado, Universidade Federal do Vale do São Francisco). Programa de Pós-Graduação em Produção Vegetal – PPGPV, Campus Petrolina, PE. https://producaovegetal.univasf.edu.br/Arquivos/anapaula.pdf

Universidade do Estado da Bahia. Programa de Pós-Graduação em Horticultura Irrigada (PPGHI) Campus Juazeiro, BA. Acessado . https://ppghi.uneb.br/b

Universidade Federal do Vale do São Francisco. Programa de Pós-Graduação em Produção Vegetal (PPGPV) Campus Petrolina, PE. Acessado . https://producaovegetal.univasf.edu.br/

Universidade Federal do Vale do São Francisco. (n.d.). Programa de Pós-Graduação em Engenharia Agrícola (PPGEA) Campus Juazeiro. Acessado . https://portais.univasf.edu.br/ppgea

Vargens, F. N. (2022). Fungos micorrízicos arbusculares como mitigador de estresse hídrico na produção de mudas de mamoeiro no Submédio do Vale do São Francisco (Dissertação de mestrado, Universidade do Estado da Bahia). Programa de Pós-Graduação em Horticultura Irrigada – PPGHI, Campus Juazeiro, BA. https://ppghi.uneb.br/wp-content/uploads/2025/02/FERNANDA-NERY-2022-1.pdf