ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2773-6202 (Online)
CODEN: JTIOCC

Journal of Technology & Innovation (JTIN)

DOI: http://doi.org/10.26480/jtin.01.2024.49.53

RESEARCH ARTICLE

A BIBLIOMETRIC ANALYSIS OF PGPR FOR MITIGATING SALINITY AND DROUGHT SALINITY

Mohideen MA and Murugan Karuppasamy*

Quality Hana Food Industries Company, Al-Qassim, Saudi Arabia.
Department of Microbiology, Sree Amman Arts & Science College, Erode District, Tamilnadu, India.
**Corresponding author e-mail address: micromurugan2013@gmail.com*

ARTICLE DETAILS

Article History:

Received 08 September 2024
Revised 11 October 2024
Accepted 15 November 2024
Available online 28 December2024

ABSTRACT

To examine how to utilize the plant growth-promoting bacteria (PGPB) and plant growth-promoting rhizobacteria (PGPR) in ameliorating drought and salinity stress conditions in agriculture, a bibliometric analysis is hereby carried out. It examines trends and patterns in scientific literature based on information collected from the Scopus database, including production from 2019 to 2024. In particular, this analysis focuses on terms associated with environmental issues, such as drought, salinity, climate change, as well as plant growth regulators. A consistent upward trend in publication is shown in this study to indicate increased interest in PGPR / PGPB and its potential application in alleviating several environmental stresses. Important conclusions indicated that a significantly large increase was directed toward studies on how PGPR / PGPB interacts with the plant hormones-gibberellins, ABA, auxin, cytokinins, and ethylene. The association of PGPR / PGPB with plant hormones in agricultural research is gradually becoming important, especially when it is associated with crop yield enhancement and stress tolerance to adverse environmental conditions. The study gives some insights into a changing research trend besides presenting the importance of PGPR / PGPB in respect to sustainable agriculture practice and development of stress-tolerant plants.

KEYWORDS

Plant growth-promoting rhizobacteria, Plant growth-promoting bacteria, Salinity stress, Drought stress, Environmental stressors, Climate change.

1. INTRODUCTION

Natural factors can pose challenges to plant reproduction, leading to stress. Salt limits the ability of plants to develop and the yield of crops in dry and semi-arid regions. Causes of secondary soil salinization are increasing as a result of human population development, excessive fertilizer, and inadequate irrigation. On October 21, 2021, the FAO made an estimate that says 8.7 percent of the Earth's surface, or 833 million hectares, is covered by salty soils in dry or semi-arid regions of Asia, Latin America, and Africa. Twenty percent to fifty percent of the world's irrigated land is affected by salt. Soils that are influenced by salt grow by 10% every year. Soil soluble salts reduce large grain crop yields by 70%, endangering global food security. A rise in agricultural production alone will not be enough to feed the world's 10 billion hungry in 2050, according to the 2018 Global Agricultural Productivity (GAP) analysis.

Soil that was previously salinized has been improved through engineering, physical, chemical, and botanical treatments. Unfortunately, there are a number of constraints. Engineering solutions necessitate effective drainage and irrigation systems; salt flushing poses challenges in regions with minimal precipitation; and chemical additives, while costly, provide only a short-term fix to salinization. Creating an atmosphere that is saltier helps plants to tolerate salt better. Through the use of transgenic technology, plants all around the globe have grown to be more salt-tolerant. There is still some disagreement. Its unsure if salt stress genes are activated by salinity. Both Manchanda and Garg were unable to find any genes that caused salt tolerance. Due of this, the impact of transgenic technology on salt stress in plants has been minimal. Incorporating microbes that promote plant growth can enhance stress tolerance and overall growth. That is why root-associated plant growth-promoting rhizobacteria (PGPR) are so important. The term PGPR was first used in 1978. Prior to the 1980s, PGPR dispersed iron-chelating siderophores, antibiotics, and hydrogen cyanide in an effort to outcompete other organisms for resources that provide energy, to make plants resistant to certain treatments, and to mineralize soil nutrients in order to reduce the prevalence of soil-borne plant illnesses and boost plant growth.

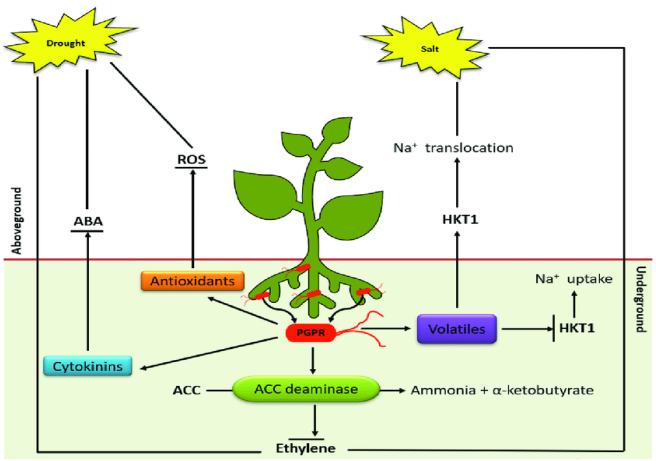

Figure 1: Mechanisms of plant growth-promoting rhizobacteria (PGPR) in mitigating abiotic stresses

Quick Response Code	Access this article online	
	Website: www.jtin.com.my	**DOI:** 10.26480/jtin.01.2024.49.53

The agricultural potential of PGPR has been partially demonstrated. The increasing number of publications, however, makes it more challenging for scholars to stay abreast of fresh discoveries. There hasn't been a systematic review of this subject, even if there have been meta-analyses and reviews that could give researchers with new ideas and basic information. Bibliometrics is a quantitative and qualitative field that tracks the development of new knowledge and technologies. Publications, cooperation network, and future research hotspot prediction are three indications that can be used to assist determine the direction and development of a topic.

2. Objectives of the Study

- To examine, the trends and patterns in 2019-2024 research literature on PGPR / PGPB in salinity and drought stress mitigation.
- To investigate how PGPR / PGPB and plant hormones such ABA, auxin, cytokinins, ethylene, and gibberellins improve plant resilience to environmental stressors.

3. Literature Review

The research displayed a meteoric rise in both publication volume and citation count (between .,1978 and Ma.,2022). As far as the organization of knowledge is concerned, Asian nations concentrated their efforts, worked closely together, and produced abundant outcomes. One of the main reasons lands degrades in dry and semi-dry areas is soil salinity, which disrupts many biological processes in plants, including photosynthesis, protein synthesis, energy metabolism, and nutritional balance. Inoculating plants with plant growth-promoting rhizobacteria (PGPR) is an eco-friendly approach to reducing salt stress and increasing salt tolerance. This bibliometric study used VOS viewer 1.6.17 and HistCite Pro 2.1 software to map the scientific knowledge of related research, review the structure of knowledge, and predict future research topics using the publications, citations, collaboration networks, and keywords from the Web of Science Core Collection (WoSCC) database.

The study investigated the effects of drought and salt stress on oats by utilizing bibliometric methods with R (4.3.1), VOS viewer (1.6.19), and cite space (6.3.1.0), as well as data from the Web of Science core database. Drought and salt stress in oats have been more widely published in the last 30 years (Huang, and Wang.,2024). The most significant intellectual contributions in the field of drought-stress research have come from two Canadian universities, Agricultural Food University and China Agricultural University, although the United States and Canada also play a significant role. Research on field crops is the most widely read journal. Growth, yield, physiological and biochemical reactions, and drought resistance have been the primary areas of oat study. Screening genotypes and modifying genes may be the focus of future oat drought research.

A research read the articles that have been peer-reviewed in order to get a feel for the current trends in the subject Sisodia, (and Sharma.,2022). The bibliometric tool employed was Scopus. Agribusiness, crop productivity, and "plant stress" were the keywords used in the search. We looked at the years 2017-2021. There were 2,207 papers on plant stress and agriculture that came up in the Scopus search. The number of publications increased with time. Chinese and Indian researchers outnumber their American counterparts in this area. Water, heat, and salt were the primary environmental factors influencing crop yields. A lot of studies concentrated on stress from water, precipitation, and drought. For agriculture to be sustainable, access to water is paramount. Particularly in rain-fed regions, conservation agricultural practices including mulching, intercropping, and no-tilling can increase crop yields while decreasing irrigation needs. There has been encouraging progress in maintaining yield with precision agriculture, which integrates hyperspectral reflectance to identify stress signals and satellite data to forecast weather and rainfall.

The analysis generated a systematic and bibliometric database of soil microbiology research that used molecular techniques to identify bacteria with agricultural potential (Dodino-Gutiérre and Santiago-Galvis.,2023). We looked for research on molecular techniques for detecting agriculturally useful microbes in the Scopus and Web of Science databases. Using the R studio program, the results were analyzed and classified. The obtained research was used to analyze the issue's origin, theoretical references, bibliometric studies, and related networks. The number of published studies on molecular approaches for finding bacteria with agricultural potential has increased by 52.75% in the last five years, with an annual growth rate of 17.4%. Currently, there are 527 such studies. With 25% of the world's total research output, India easily ranks as the most prolific publishing nation. Common methods for determining which microbes may be present include polymerase chain reaction (PCR) and sequencing.

A study investigated the role of endophytic bacteria in enhancing wheat's tolerance to drought and salinity through a comprehensive evaluation (Al-Hawamdeh.,2024). The review highlights information gaps, discusses the implications for sustainable agriculture, and analyses research trends and physiological mechanisms. From 2004 to 2023, the literature on endophytic bacteria in wheat was reviewed using databases from major publishers. The review delves into their mechanisms, which involve producing phytohormones and activating genes that respond to stress, to emphasize their function in plant development and resilience. Studies have focused on understanding their physiological reactions and interactions with wheat plants. There is a growing interest in employing endophytic bacteria to alleviate these pressures in wheat agriculture, according to current research trends. It would be great if future research could provide light on the endophytic lifestyle, mechanism of action, transmission pathways, and how exactly endophytic bacteria increase host plant resilience to different stimuli. Endophytic bacteria, in general, provide promising avenues for environmentally responsible agricultural practices, bolstering both food security and the ability of crops to withstand environmental stresses.

Some research investigated the effects of salt stress on the motility, biofilm formation, and auto aggregate capabilities of three plant-growth-promoting bacterial strains. Pseudomonas putida SJ04, Pseudomonas simiae WCS417r, and Bacillus amyloliquefaciens GB03(Cappellari.,2023). In order to grow these strains, lactose broth (LB) medium that had been diluted was supplemented with 0-, 100-, 200-, or 300-mM sodium chloride (NaCl). Conditions with 0.3 and 0.5% agar, respectively, were used to evaluate swimming and swarming mobility. Spectrophotometry was used to evaluate the auto aggregation capacity, whereas the crystal violet method was employed to quantify the biofilm formation capacity. We also tested the strains' capacity to reduce Mentha piperita's in vitro response to salt stress. The study found that the GB03 strain exhibited better swarming motility as the salt concentration in the medium grew, leading to a halo diameter that doubled at 300 mm yet, swimming mobility was unaffected by high sodium chloride concentrations. On the other hand, SJ04 and WCS417r showed a reduction in swimming motility when exposed to salt stress. On the other hand, WCS417r showed a 30% increase in auto aggregation and a 180% rise in biofilm growth when exposed to 300 mM sodium chloride. The auto aggregation percentage of strains SJ04 and GB03 was unaffected by saline stress.

The analysis aimed to better understand the interplay between plants and microbes, future research should aim to quantify the relationships between these two factors, conduct field testing over longer periods of time, and focus squarely on food crops. Future crop varieties that are more drought-resistant may be enhanced by root-associated microbes, which already improve plant growth. Our grasp of the complex feedback loops between plant and microbial responses to drought is expanding, but much of what we know comes from studies conducted on non-crop plants in controlled environments. We conclude that more research into the mechanisms behind the complex interactions between plants and microbes during and after drought is necessary de (Vries Griffiths.,2020). This necessitates integrating ecological, plant, microbial, and molecular methods in order to make agricultural output more resistant to the climate changes that are likely to occur in the future.

Discussed the challenges and opportunities for future research on zinc nanoparticles (ZnNPs) for environmentally friendly farming. Zinc (Zn) is essential for plant health, however there are a lot of factors that limit its availability in soils (Jafir.,2024). Nanotechnology has the potential to improve plant tolerance to abiotic stress by boosting zinc absorption and delivery. Zinc nanoparticles have shown promise in alleviating abiotic stress in plants, however there is a paucity of comprehensive reviews of recent advances and emerging research trends in this area. In order to conduct the bibliometric analysis for this work, we consulted the Web of Science Core Collection, which contains 6932 entries published between 2000 and 2020. We set out to catalogue the leading countries, organizations, journals, authors, and key terms that have shaped the evolution of zinc nanoparticles research toward mitigating abiotic stresses in plants. Along with this bibliometric analysis, we looked at the methods, applications, and processes of zinc nanoparticles synthesis to improve photosynthesis and plant growth in response to various abiotic stress conditions. Our findings showed that green synthesis was the most popular method for producing zinc nanoparticles, and that the top three countries involved in zinc nanoparticles research were Iran, China, and India. We also found that zinc nanoparticles enhanced plant resistance to abiotic stress by influencing many biochemical, physiological, and molecular pathways.

A study explored the potential of microbiome engineering and plant bio stimulants as a long-term solution to the problems of biotic and abiotic stress, inefficient nutrient use, stunted plant growth, and low agricultural productivity (Lau.,2022). There is already a lot of food being produced from farms around the world, but new plant diseases and the consequences of climate change are going to cut into that. An ever-increasing increase in agricultural production to sustain human population growth has come at the price of our planet's ability to produce enough food for everyone. To avoid using synthetic fertilizers and pesticides, sustainable farming practices are more important. An eco-friendly approach that has gained traction is the use of plant microbiome engineering and (natural) biostimulants to increase crop tolerance to adverse weather conditions and increase agricultural productivity. To further our understanding of plant-biostimulant interaction, it is crucial to conduct current scientific study to determine how much benefit these biostimulants provide in challenging situations. Mapped out the current state of knowledge about phytoremediation of heavy metals (HMs) by analysing research trends, hotspots, and other relevant data. The 6873 articles covered in this study pertain to heavy metal phytoremediation on a worldwide scale and were retrieved from the Web of Science Core Collection (WoSCC .,2019). The two applications that were used for processing were CiteSpace and Bibliometrix. This field of study is characterized by a boom in the number of subject categories related to engineering applications and a high degree of interdisciplinary collaboration. The main supporting categories were "Agriculture," "Environmental Sciences & Ecology," and "Plant Sciences." On top of that, "Engineering, Multidisciplinary," "Engineering, Chemical," and "Green & Sustainable Science & Technology" are some of the most popular categories right now. The main areas of focus for study were determined to be "soil," "hyperaccumulator," "enrichment mechanism/process," and "enhance technology." Among the most notable developments in the field of study are the terms "agromining," "field crops," "wastewater," and "genetically engineered microbes / plants." When it comes to HM phytoremediation, bibliometric and scientometric analysis are great tools for quantitative and qualitative measurement of research hotspots and trends. Additionally, they can be a great resource for new researchers who are just starting to scour the literature for answers.

4. Research Methodology

4.1 Research Design

The purpose of the research is to identify patterns, trends, and associations of the scientific literature in plant growth-promoting rhizobacteria (PGPR) and plant growth-promoting bacteria (PGPB) regarding the reduction of salinity and drought stress in agriculture. Therefore, the present research employs a quantitative design, utilizing the bibliometric analysis technique that considers massive published research based on bibliometric techniques which emphasize frequency, distribution, and co-occurrence of certain keywords and topics concerning the study.

4.2 Data Collection

One of the largest databases that index peer-reviewed literature, Scopus (Elsevier), was employed to collect data for this study. The following procedure was followed to collect data:

- **Keywords:** PGPR, PGPB, salinity, drought, and other keywords that are related to environmental, like climate change, desert, and degraded soil are used as the primary terms in the search for this study. The time frame of articles to include was from 2019-2024.
- **Search Strategy:** Studies that explicitly dealt with the role of PGPR / PGPB in mitigating drought stress and salinity were included in the search query. This was done by selecting articles based on specific plant growth regulators and environmental keywords.
- **Inclusion criteria:** Only peer-reviewed, English language journal publications, which talked about drought stress, salinity, and PGPR / PGPB related to agricultural and plant growth.
- **Exclusion criteria:** Sources that are not peer reviewed, articles in languages other than English, and did not specifically refer to PGPR / PGPB were excluded.

4.3 Tools and Software

Multiple tools and software have been applied in this research to analyze the data. The tidy verse was for data wrangling while using the text miner in creating the DTM as well as TF-IDF. R Studio v.2023.06.1+524 was used to perform cleaning, modification, as well as text mining. To visualize the associations between terms according to their frequency and co-occurrence in publications, keyword clustering maps were generated using VOS viewer for co-occurrence network analysis. The tools would be essential for processing and evaluating the data in order to find important research trends and insights in the field of PGPR / PGPB.

4.4 Data Analysis

The literature trends and patterns were sought by using the bibliometric method of this study. Descriptive analysis was utilized to quantify and evaluate the number of published papers and their normalized percentages for each year (2019-2024) to identify the patterns in research output. TF-IDF was applied to find influential keywords and determine the correlation between phrases such as PGPR, PGPB, drought, and salinity. VOS viewer was used to find research theme clusters and the visual relationship of keywords between the publications over time using hierarchical clustering and co-occurrence network analysis. PGPR / PGPB, salinity, and drought articles increased with time, thereby showing an increase in concern for these environmental stresses. Finally, graphs and charts were developed to show the pattern of publication, keyword frequencies, and co-occurrence networks to identify the major research areas and whether PGPR / PGPB affects environmental issues.

5. Data Analysis

Table - 1 depicts the quantity and normalized percentage of published papers regarding PGPB and PGPR on Plant Growth-Promoting Rhizobacteria, from the period of 2019 till 2024. Both, in terms of quantity published papers, and normalized percent have experienced growth throughout these years.

Table 1: Normalized published papers on PGPR / PGPB by number and percentage (2019-2024)

Year	Number of Published Papers	% of Normalized Published Papers
2019	750	0.050
2020	800	0.060
2021	850	0.070
2022	900	0.090
2023	950	0.100
2024	1000	0.110

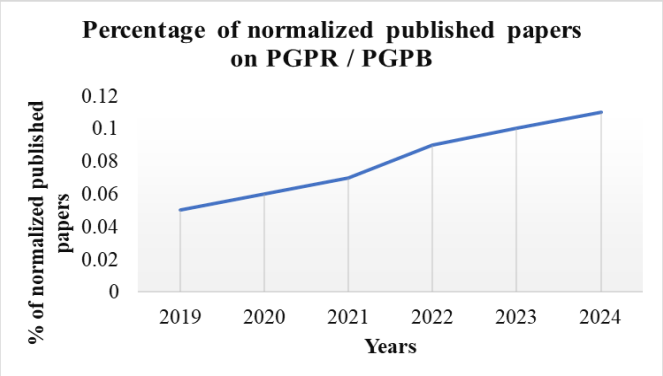

Figure 2: Normalized published papers on PGPR / PGPB by number and percentage (2019-2024)

Table - 1 represents this trend of increasing interest through research by showing that the number of articles published has increased from 750 in 2019 to 1,000 in 2024. Similarly, normalized percentage of published papers is shown to climb steadily from 0.050% in 2019 to 0.110% in 2024, indicating a growing share of the total scientific literature devoted to PGPR / PGPB. This pattern indicates growing awareness about the role these bacteria play in promoting plant growth and increasing agricultural productivity, which is likely spurred by advances in agricultural biotechnology, environmentally friendly agriculture, and sustainable agriculture.

Table - 2 shows normalized percentage of 2019-2024 PGPR / PGPB publications by environmental keywords. The table indicates an increase in climate change, drought, and salinity papers but steady desert and damaged soil papers. Climate change publications rise from 0.004% in 2019 to 0.006% in 2024, while both drought and salinity have risen, indicating growing attention on these environmental issues. Desert and salt-infested soils are still within the realm of research interest though

their pace is not surging like climate change, aridity, and salinization. This trend mirrors the dawning recognition on the PGPR / PGPB ability to alleviate such climate change, drought and soil salinization. These factors are essential for ensuring modern agricultural sustainability and environmentally friendly management.

Table - 2: PGPR / PGPB published papers by environmental keywords, normalized percentage (2019-2024)

Year	Climate Change (%)	Desert (%)	Degraded Soil (%)	Drought (%)	Salinity (%)
2019	0.004	0.001	0.002	0.010	0.015
2020	0.005	0.001	0.003	0.011	0.016
2021	0.005	0.001	0.003	0.011	0.017
2022	0.004	0.001	0.002	0.012	0.016
2023	0.005	0.001	0.003	0.013	0.018
2024	0.006	0.001	0.003	0.014	0.019

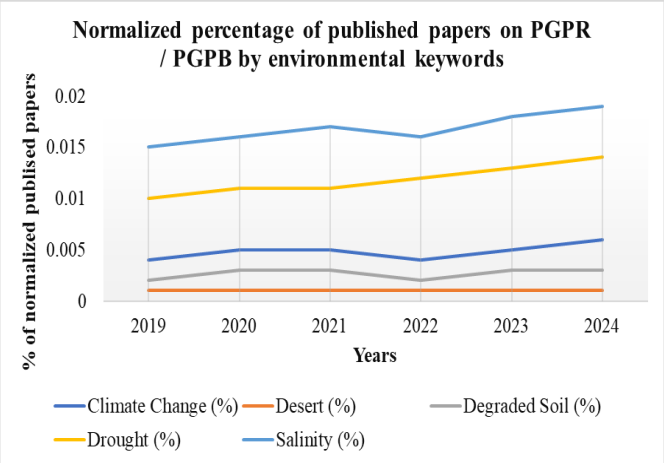

Figure 3: PGPR / PGPB published papers by environmental keywords, normalized percentage (2019-2024)

Table 3: Normalized publications on combined keywords that contain "PGPR" or "PGPB"

Year	% of Published Papers on ABA or Abscisic Acid	% of Published Papers on Auxin	% of Published Papers on Cytokinins	% of Published Papers on Ethylene	% of Published Papers on Gibberellins
2019	0.0055	0.007	0.0045	0.005	0.0025
2020	0.006	0.008	0.005	0.0055	0.003
2021	0.0065	0.009	0.0055	0.006	0.0035
2022	0.007	0.010	0.006	0.0065	0.004
2023	0.0075	0.011	0.0065	0.007	0.0045
2024	0.008	0.012	0.007	0.0075	0.005

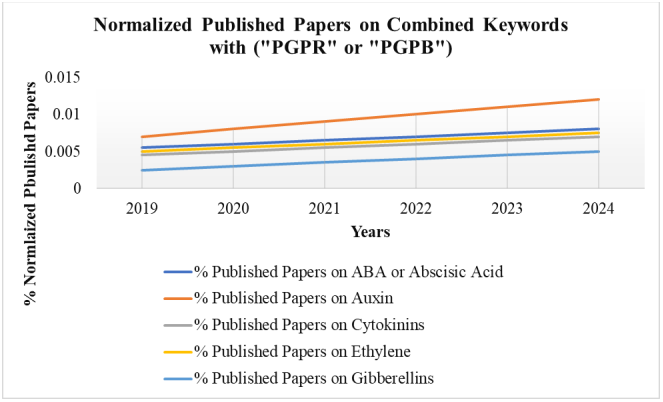

Figure 4: Normalized publications on combined keywords that contain "PGPR" or "PGPB"

Table - 3 lists the normalized percentages of publications published on plant growth regulators (PGPR / PGPB) with several plant hormones including ABA or abscisic Acid, auxin, cytokinins, ethylene, and gibberellins. There has been a steady rise in the research on all five plant hormones from 2019 to 2024 as shown in the table. Each year, the number of published works on ABA, auxins, cytokinins, ethylene, and gibberellins is on an annual rise, suggesting that the involvement in study of the interactions between PGPR / PGPB and those hormones is on an increased trend in agricultural and environmental contexts. As seen with Auxin, this study shows a similar tendency upward to 0.012% by 2024; similarly, with the articles on ABA percentage showing increases from 0.0055% in 2019 to 0.008% in 2024, showing the rising interest paid toward these plant hormones, where functions in improving plant resilience and growth, particularly in response to environmental stresses such as salinity and drought, that are usually studied together with PGPR / PGPB. Taken collectively, the evidence points toward a growing corpus of studies related to the PGPR / PGPB and its relation to regulation through plant hormone, thereby emphasizing the prospects to bring the agricultural sustainability and production further upward.

5. Conclusion

This bibliometric study concludes by pointing out an augmented comprehension of the role played by PGPR and PGPB in overcoming the stresses of drought and salinity which indicates a major stride to the sustainable farming methodology. Research output has been continually enhancing as indicated by the report with specific focus on the understandings of the connections PGPR / PGPB made with plant hormones as emphasizing the ability of these microorganisms towards improving plant growth and resistance against ecological stressors. The results show encouraging implications of raising crop productivity and sustainability, which point to the necessity of further research into PGPR / PGPB as a useful tool in agricultural biotechnology. Trends in current research suggest that PGPR / PGPB will become more and more important in solving environmental problems including climate change, drought, and salinity besides promoting sustainable farming methods.

References

Ma, X., Pan, J., Xue, X., Zhang, J., and Guo, Q., 2022. A promoting rhizo. A, 12 (10), Pp. 2304. DOI:10.3390/agronomy12102304.

Huang, H., Wang, X., Li, J., Gao, Y., Yang, Y., Wang, R., Zhou, Z., Wang, P., and Zhang, Y., July 2024. Trends and directions in oats research under drought and salt stresses: a bibliometric analysis (1993-2023). Plants, 13(14)Pp., 1902. https://doi.org/10.3390/plants13141902.

Sisodia, R., and Sharma, R., November 2022. Bibliometric analysis of peer-reviewed literature on stress factors affecting agricultural productivity. Current Agriculture Research Journal, 10(3), Pp.,170-180. DOI:10.12944/CARJ.10.3.02.

Dodino-Gutiérrez, C. A., Santiago-Galvis, J. M., Rabelo-Florez, R. A., and Cubillos-Hinojosa, J. G., August 2023. Application of molecular techniques in soil microbiology for the identification of bacteria with agricultural potential: a review and bibliometric analysis. Revista Colombiana de Ciencias Hortícolas, 17(2)Pp., e16096. https://doi.org./10.17584/rcch.2023v17i2.16096.

Al-Hawamdeh, F., Ayad, J. Y., Alananbeh, K. M., and Akash, M. W., May 2024). Bacterial endophytes and their contributions to alleviating drought and salinity stresses in wheat: a systematic review of physiological mechanisms. Agriculture, 14(5)Pp., 769. DOI:10.3390/agriculture14050769.

Cappellari, L. D. R., Bogino, P. C., Nievas, F., Giordano, W., and Banchio, E., December 2023. Exploring the differential impact of salt stress on root colonization adaptation mechanisms in plant growth-promoting

rhizobacteria. Plants, 12(23)Pp., 4059. DOI:10.3390/plants12234059.

de Vries, F. T., Griffiths, R. I., Knight, C. G., Nicolitch, O., and Williams, A., April 2020. Harnessing rhizosphere microbiomes for drought-resilient crop production. Science, 17;368(6488), 270-274. DOI: 10.1126/science.aaz5192.

Jafir, M., Khan, A., Ahmad, A., Hussain, K., Zia-ur-Rehman, M., Nazeer Ahmad, S. J., Irfan, M., Azeem Sabir, M., Turabi, T. H., and Zulfiqar, U., March 2024. Zinc nanoparticles for enhancing plant tolerance to abiotic stress: a bibliometric analysis and review. Journal of Soil Science and Plant Nutrition, 24, 1704-1719. https://doi.org/10.1007/s42729-024-01733-w.

Lau, S. E., Teo, W. F. A., Teoh, E. Y., and Tan, B. C., February 2022. Microbiome engineering and plant biostimulants for sustainable crop improvement and mitigation of biotic and abiotic stresses. Discover Food, 2(1),Pp.,9. DOI:10.1007/s44187-022-00009-5.

Li, C., Ji, X., and Luo, X., November 2019. Phytoremediation of heavy metal pollution: a bibliometric and scientometric analysis from 1989 to 2018. International Journal of Environmental Research and Public Health, 16(23)Pp., 4755. DOI: 10.3390/ijerph16234755.