Jurnal Agro Wiralodra
Volume 9, Nomor 2, Juli 2026 |
ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

# Effects Of Photosynthetic Bacteria Fertilizer and Push-Pull System On Growth And Yield Of Maize (*Zea mays*)

Victor Bintang Panunggul[1*], Niken Hapsari Arimurti Susanto[1], Ayu Sitanini[1], Zaenal Abidin[1]

[1] Program Studi Agribisnis, Fakultas Sains dan Teknik, Universitas Perwira Purbalingga
*victorbintang92@gmail.com*

**Abstract**

Marginal soils are characterized by low nutrient availability, which adversely affects crop productivity. The incorporation of organic materials and cultivation techniques plays an important role in maintaining soil health and crop yield. This study aimed to evaluate the effects of photosynthetic bacterial fertilizers and the push-pull system cultivation technique. The research was conducted in Banjaran Village, Purbalingga Regency, utilizing a completely randomized block design. Treatments tested included S0 (control), S1 (50 mL/2L), and S2 (100 mL/2L), as well as P0 (control), P1 (lemongrass), and P2 (peanuts). Each treatment was replicated three times and analyzed using ANOVA, with Duncan's Multiple Range Test (DMRT) (α=5%) applied for significant differences. The observed variables included fresh plant weight, leaf area, fresh root weight, age of male flowers, and chlorophyll a levels. The results indicate that the application of photosynthetic bacteria significantly affects the fresh weight of the plants and the age of male flowers. However, there is no significant effect on leaf area, fresh root weight, and chlorophyll a levels. The push-pull system cultivation technique significantly affects chlorophyll a levels, although no significant differences were found in fresh plant weight, leaf area, fresh root weight, and age of male flowers.

**Keywords:** *Corn; Peanuts; Podzolic; Purbalingga; PSB*

**Abstrak**

Tanah marginal mengandung unsur hara rendah dan menurunkan hasil tanaman. Penggunaan bahan organik dan teknik budidaya berperan untuk menjaga Kesehatan tanah dan hasil tanaman. Studi ini bertujuan untuk menentukan pengaruh pupuk bakteri fotosintetis dan teknik budidaya pull push system. Penelitian dilaksanakan di Desa Banjaran, Kabupaten Purbalingga, dengan menggunakan desain blok acak lengkap. Perlakuan yang diuji mencakup S0 (kontrol), S1 (50 mL/2L), dan S2 (100 mL/2L), serta P0 (kontrol), P1 (serai), dan P2 (kacang tanah). Setiap perlakuan direplikasi sebanyak tiga kali dan dianalisis menggunakan ANOVA, dengan Uji Rentang Ganda Duncan (DMRT) (α=5%) diterapkan untuk perbedaan yang signifikan. Variabel yang diamati meliputi berat segar tanaman, luas daun, berat akar segar, umur bunga jantan, dan kadar klorofil a. Hasil penelitian menunjukkan bahwa aplikasi bakteri fotosintetik berpengaruh signifikan terhadap berat segar tanaman dan umur bunga jantan. Namun, tidak terdapat pengaruh signifikan terhadap luas daun, berat akar segar, dan kadar klorofil a. Teknik budidaya pull push system menunjukkan pengaruh signifikan terhadap kadar klorofil a, meskipun tidak ditemukan perbedaan signifikan dalam berat segar tanaman, luas daun, berat akar segar, dan umur bunga jantan.

**Kata kunci:** Jagung; Kacang; Podzolik; Purbalingga; PSB

## Introduction

Corn (*Zea mays* L.) is recognized as one of Indonesia’s key strategic food commodities, ranking after rice and soybeans because of its significant contribution as a carbohydrate source, livestock feed ingredient, and essential raw material for both the food processing and bioethanol industries (Winarti *et al*., 2023). Corn is crucial to ensuring that people have access to enough food. The maize yield in Bojongsari District, Purbalingga Regency, declined from 6.60 t ha$^{-1}$ in 2023 to 5.55 t ha$^{-1}$ in 2024 and 5.08 t ha$^{-1}$ in 2025 (Badan Pusat Statistik Kabupaten Purbalingga, 2026). Corn is a versatile crop capable of thriving under a wide range of environmental conditions (Ahmad *et al*., 2020; Kurosawa *et al*., 2020; Prasanna *et al*., 2021). Environmental factors can hinder the development process and reduce crop yields (Chaudhry & Sidhu, 2022; Chieb & Gachomo, 2023).

Appropriate fertilization and the implementation of sound cultivation practices are key determinants of crop productivity. Soil fertility decline driven by the intensive and continuous use of chemical fertilizers is a major contributor to reduced productivity. Dependence on these inputs has led to degraded soil structure, diminished populations of beneficial microorganisms, and lower nutrient uptake efficiency (Nair, 2025). Organic amendments and appropriate farming practices improve soil environmental quality by enhancing nutrient availability, increasing soil organic matter, and promoting microbial activity (Durán-Lara *et al*., 2020; Shaji *et al*., 2021). Red-


Diterbitkan oleh Program Studi Agroteknologi Fakultas Pertanian Universitas Wiralodra

ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

yellow podzolic soils pose cultivation challenges due to pronounced acidity and very low nutrient availability, and the application of organic amendments together with enhanced agronomic practices can alleviate these constraints and help maintain environmental quality (Liu *et al*., 2019). In the context of sustainable agriculture, efforts to improve these conditions need to focus on the use of biological agents and crop cultivation techniques. One such example is photosynthetic bacteria and the push-pull cultivation technique.

Photosynthetic bacteria constitute heterotrophic microorganisms capable of performing anoxygenic photosynthesis (George *et al.,* 2020) and they contribute critically to soil nitrogen, carbon, and sulfur cycling (Kushkevych *et al*., 2024). Representative species frequently employed include *Rhodopseudomonas palustris* and *Rhodobacter sphaeroides*. *Photosynthetic bacteria* (PSB), are a kind of bacteria that create their own food using sunlight (Gunaseelan *et al*., 2024; Lu *et al*., 2022). PSB has pigments that play a role in promoting photosynthesis (Labunskaya *et al*., 2024; Wang *et al*., 2020). Application of 20 mL of photosynthetic bacterial liquid fertilizer resulted in a dry weight of 21.04 g for kailan plants (Panunggul *et a*l., 2023). The push-pull cultivation system improves the use of space and resources. This study offers sustainable strategies for farmers to enhance crop yields and encourages the adoption of environmentally friendly agricultural practices. The push–pull system is an integrated cropping approach that combines main crops, companion plants, and habitat management to suppress pests and diseases and protect crop health (Gugissa *et al*., 2022) and eco-friendly (Buleti *et al*., 2023).

This study investigates fertilizers derived from photosynthetic bacteria and a method called push-pull that can help grow more corn. Previous research by (Dursun *et al*., 2019), the application of bacterial fertilizer at a concentration of 3 gL-1, has no effect on chlorophyll 56,60 µg mL-1 and effect of purple bacteria that help with phosphate makes pea plants take in less (Wang *et al*., 2021). Inoculation with photosynthetic bacteria enhanced rice growth and productivity, increasing plant height by up to 12% and grain yield by 18% relative to the control (Ikhwani *et al*., 2022). Nawaz *et al.* (2023), demonstrated that application of photosynthetic bacteria to soybean plants enhanced photosynthetic activity and elevated leaf chlorophyll content. The push–pull system involving Desmodium plants influences only the ground cover vegetation, while planting distance determines the degree of competition for light and nutrients (Mutyambai *et al*., 2019). The application of push–pull technology using DNA genome extraction has not succeeded in identifying the microbial taxa present in maize roots under the current experimental conditions (Jalloh *et al*., 2024). The novelty of this study lies in using pond water, bamboo root extract, *Pseudomonas fluorescens*, and fermented spirulina extract to cultivate photosynthetic bacteria that function as plant hormones, immunological agents, and soil nutrients within the experimental framework. The previously implemented push-pull system has not achieved optimal crop yields despite Desmodium's role as a mitigator of soil degradation. However, Desmodium does not promote Rhizobium formation. Consequently, the proposed study will evaluate the use of lemongrass for pest and disease repellence and peanut (*Arachis hypogaea*) as a nitrogen-fixing crop to improve yield performance under the specified experimental conditions. The study aims to determine the effects on the growth, physiology, and yield of corn plants.

## Materials and Method

Research was conducted on land in Banjaran Village, Bojongsari, Purbalingga, Indonesia, located at an altitude of 145 meters above sea level. The research materials used included "Exotic" F1 hybrid sweet corn seeds, distilled water, acetone, alcohol, NPK Mutiara fertilizer, chemicals for filter paper, label paper, 0.5 kg plastic, tissue, effective microorganisms 4, Bio-P60, and pesticides. The tools used included test tubes, measuring pipettes, measuring cups, Erlenmeyer flasks, beakers, spectrophotometers, polybags, ovens, analytical scales, seed counters, porcelain cups, cuvettes, and writing instruments.

The variables included fresh plant weight, leaf area, fresh root weight, age of male flowers, and chlorophyll a. The experimental design used in this study was a Randomized Complete Block Design (RCBD). The first factor tested was liquid organic fertilizer, consisting of three levels: S0 (control), S1 (50 mL/2L), dan S2 (100 mL/2L). The second factor is pull push system, terdiri tiga taraf: P0 (control), P1 (Lemongrass), dan P2 (peanuts). The combination of the two factors above resulted in 9 treatments, which were then repeated 3 times, resulting in 27 experimental units. The data were analyzed using DSAASTAT 1.1. and Analysis of variance (Anova) test. The results of the treatments were analyzed using the Duncan Multiple Range Test (DMRT) with a 95% confidence level.

ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

*Photosynthetic bacterial fertilizer*

Fermentation of photosynthetic bacterial fertilizer using fish pond water and bamboo root fermentation. Place 500g of bamboo roots in a fermentation container. Next, mix in 10 L of fish pond water, then mix in 100g of brown sugar. Then pour into a container and add 25 mL of EM-4 liquid microorganism starter solution and the fermented spirulina from fish pond water, then stir until evenly mixed. After that, pour in 25 mL of Bio P60. Then store for 14 days until the color turns pink.

## Result and Discussion

The results of the data analysis regarding the treatment of photosynthetic bacterial fertilizer on growth variables showed a significant difference in the fresh weight of the plants. However, no significant differences were observed in leaf area. The application of photosynthetic bacterial fertilizer significantly affected the female flower variable, while there was no significant difference in the wet weight of the plants. Additionally, the application of photosynthetic bacterial fertilizer did not show a significant difference in chlorophyll a levels.

*Fresh Weight Of The Plant*

The application of photosynthetic bacteria fertilizer at a concentration of 100 mL/2 L resulted in a significantly higher fresh plant weight of 95.74 g compared to the other treatments. This concentration effectively promoted vegetative growth, leading to greater fresh biomass accumulation. The enhanced growth performance may be associated with the ability of photosynthetic bacteria to improve nutrient uptake efficiency and stimulate the biological activity of the growing medium, thereby supporting overall plant growth and development. The presence of photosynthetic bacteria, such as *Rhodobacter sphaeroides*, increases nitrogen availability through atmospheric nitrogen fixation. The enhanced nitrogen supply supports protein and nucleic acid synthesis, which subsequently stimulates plant growth and contributes to greater biomass production (Anh *et al*., 2025). Additionally, these bacteria produce phytohormones such as auxins and cytokinins, which promote cell division and elongation, as well as enhance the development of vascular tissues (Etesami, 2025). Efficient water and nutrient translocation enhances chlorophyll production, which increases photosynthetic activity and promotes fresh biomass accumulation (Six *et al*., 2024).

The push–pull cultivation technique did not significantly influence fresh plant weight. However, the treatment with peanut plants produced a fresh plant weight of 95.33 g. Although the effect was not statistically significant, the presence of peanut plants may have enhanced nutrient availability and supported plant growth, leading to greater fresh biomass accumulation under the study conditions. This can be explained through the adaptation mechanisms of plants that adjust their physiological and metabolic responses to maintain growth, even under competitive conditions with repellent plants (Isah, 2019). Plants prioritize root and leaf growth under these conditions, which supports higher photosynthetic efficiency (Moosavi-Nezhad *et a*l., 2022).

*Leaf area*

The application of photosynthetic bacteria fertilizer did not significantly affect leaf area among treatments. However, the application of 100 mL/2 L resulted in the highest leaf area value of 82.28 cm². Photosynthetic bacteria appeared to promote leaf expansion, indicating that their association with plants enhances nutrient availability, while overall leaf area remained largely unchanged. Liquid fertilizers containing photosynthetic bacteria can increase chlorophyll accumulation, which plays a role in photosynthesis (Anli *et al*., 2020). However, the enhancement of photosynthetic capacity does not always correlate with the expansion of leaf area. Photosynthetic bacteria synthesize phytohormones that promote cell division and elongation; however, leaf development largely depends on environmental conditions, including light and humidity (Kamyab *et al*., 2025).

The push-pull system cultivation technique aims to enhance plant resistance to pests by utilizing repellent plants grown around the main crops. This technique successfully suppresses pest attacks; however, it does not result in significant changes in the leaf area of the main crop. Competition for light and nutrients between the main crop and companion plants may explain the observed response (*Moreau et al*., 2025). The presence of repellent plants can decrease light interception by the main crop, which may restrict. photosynthetic activity and leaf expansion. In addition, humidity and temperature strongly influence leaf area development, regardless of improved nutrient availability (Yang *et al*., 2025).

ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

**Table 1.** The Effect of Photosynthetic Bacterial Fertilizer and Cultivation Techniques on Corn Plants.

| Treatment | FWP (g) | LF ($cm^2$) | FRw (g) | MFA | Chla (mg $g^{-1}$ ) |
|---|---|---|---|---|---|
| Doses Pb | | | | | |
| S0 (Control) | 94,78 a | 81,16 a | 15.66 a | 8,13 a | 8,63 a |
| S1 (50 mL/2L) | 95,32 b | 81,53 a | 15.71 a | 8,55 b | 8,83 a |
| S2 (100 mL/2L) | 95,74 c | 82,28 a | 15.94 a | 8,91 c | 8,97 a |
| CV | 1,1 | 2,61 | 6,75 | 7,24 | 3,73 |
| Push-pull | | | | | |
| P0 (Control) | 95,13 a | 80,71 a | 15.76 a | 8,58 a | 8,32 a |
| P1 (Lemongrass) | 95,24 a | 81,67 a | 15.93 a | 8,59 a | 8,68 b |
| P2 (Peanuts) | 95,33 a | 82,67 a | 15.63 a | 8,46 a | 9,39 c |
| CV | 1,1 | 2,61 | 6,75 | 7,24 | 3,73 |

Note: CV: Coefficient of Variation; FWP:Fresh Weight Plant; LF: Leaf area; FRw: Fresh root weight; MFA: Male Flower Age; Chla: Chlorophyll a. Based on the Duncan's multiple range test at a significance level of 5%, the means followed by the same lowercase letters in the same column are not significantly different.

*Fresh Root Weight*

The application of photosynthetic bacteria fertilizer did not significantly affect fresh root weight. However, the application of 100 mL/2 L resulted in a fresh root weight of 15.94 g. The interaction between bacteria and plants can explain the underlying mechanism by enhancing nutrient availability, although this interaction does not consistently produce a significant increase in fresh root biomass accumulation. Liquid fertilizers containing photosynthetic bacteria can increase soil microbial activity and the availability of essential nutrients such as nitrogen and phosphorus, which are important for root growth (Allouzi *et al*., 2022). This increase may be insufficient to significantly stimulate root growth under certain environmental conditions. Environmental factors such as soil moisture and temperature, along with plant genetic status, can also affect resource allocation to roots, thereby influencing total fresh root weight (Miao *et al*., 2024).

The push–pull cultivation technique did not significantly influence fresh root weight. However, the treatment with lemongrass resulted in a fresh root weight of 15.93 g. Although the effect was not statistically significant, the presence of lemongrass may have improved rhizosphere conditions and supported root growth, leading to greater fresh root biomass accumulation under the study conditions. The underlying mechanism may be related to competition between the main plants and the repellent plants for resources such as water, light, and nutrients (Akbar *et al*., 2024).

Repellent plants can decrease light availability to the main crops, potentially impairing photosynthesis and reducing the energy available for root development. Although the push–pull technique can enhance overall plant health, environmental variables uch as soil moisture, temperature, and soil microbiological status also critically influence root growth (Long *et al*., 2023).

*Male Flower Age*

The application of photosynthetic bacteria fertilizer did not significantly influence the age of male flowering. However, the 100 mL/2 L treatment resulted in a male flowering age of 8.91 days. Photosynthetic bacteria may have increased nutrient availability and supported reproductive development, thereby advancing flowering time, although this effect did not reach statistical significance. Photosynthetic bacteria enhance nutrient availability and promote plant growth, although they do not consistently influence the onset of male flowering in maize. The timing of male flowering largely depends on genetic characteristics, environmental conditions, and the availability of water and essential macronutrients. The differentiation of the apical meristem leads to the development of male flowers at the stem apex. During the vegetative phase, male flower primordia form tassels containing anthers that generate pollen (Cardarelli & Cecchetti, 2014). Wind carries pollen from the anthers to the silks of female

ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

flowers, where successful fertilization leads to kernel formation (Liu *et al*., 2023).

The application of the push-pull system cultivation technique has no significant effect on the age of male corn flowers. Peanut plants support the cropping system by fixing atmospheric nitrogen in root nodules, and the nitrogen released from these nodules enhances soil fertility and increases nutrient availability for maize (Guo *et al*., 2023). Improved nutrition can support plant growth, but factors such as genetics and environmental conditions remain the main determinants of the timing of male flower emergence, or tasseling (Chaudhry *et al*., 2024; Dong *et al*., 2024). The process of male flower formation in corn plants begins when the apical meristem differentiates into flower primordia. Nitrogen derived from peanuts enhances vegetative development during the growth phase; however, tassel emergence remains largely unaffected. Following tassel formation, the anthers initiate pollen production (Amin, 2011).

*Chlorophyll a*

Photosynthetic bacteria treatment did not produce a statistically significant difference in chlorophyll a levels. However, the 100 mL/2 L dose resulted in a chlorophyll a concentration of 8.97 mg $g^{-1}$. Chlorophyll a levels are more influenced by factors such as light intensity, nitrogen and magnesium availability, and the overall physiological condition of the plant. The effect of *Good Grow* fertilizer showed the highest total chlorophyll content at a dose of 5 ml/L, at 11.10 mg $g^{-1}$ (Nasution *et al*., 2025).

The push–pull cultivation technique produced a statistically significant effect on chlorophyll a levels. Specifically, the push–pull system applied to peanut resulted in a chlorophyll a concentration of 9.39 mg $g^{-1}$ . Peanuts act as an intercrop that provides nitrogen through fixation by rhizobium bacteria in their root nodules (Zhang *et al*., 2024). Nitrogen derived from peanuts improves soil fertility and supports crop growth, but its influence on chlorophyll a levels may remain limited (Evans & Qaderi, 2024). Factors such as light intensity, magnesium supply, and plant physiological condition exert a greater influence on chlorophyll a accumulation than nitrogen availability.

## Conclusion

1. The results of the study concluded that the application of photosynthetic bacteria significantly affected the fresh weight of the plants and the age of male flowers. However, the influence of photosynthetic bacteria did not have a significant effect on leaf area, fresh root weight, and chlorophyll a levels.
2. The push-pull system cultivation technique significantly affected chlorophyll a levels. However, no significant differences were observed in the fresh weight of the plants, leaf area, fresh root weight, and age of male flowers. The combined application of photosynthetic bacteria fertilizer and the push–pull cultivation system did not result in a significant interaction effect on plant growth, yield, or physiological responses.

## Acknowledgments

The author would like to thank the Directorate of Research and Community Service (DPPM) for funding the Early Career Faculty Research Program (PDP) under number 127/C3/DT.05.00/PL/2025.

## References

Ahmad, I. Ahmad, B. Boote, K. & Hoogenboom, G. (2020). Adaptation Strategies For Maize Production Under Climate Change For Semi-Arid Environments. *European Journal of Agronomy*, *115*(March), 126040. https://doi.org/10.1016/j.eja.2020.126040

Ajeigbe, K. B., & Ganda, F. (2024). Leveraging Food Security and Environmental Sustainability in Achieving Sustainable Development Goals : Evidence from a Global Perspective. *Sustainability*, *16*(18), 1–22. https://doi.org/https://doi.org/10.3390/su16187969

Akbar, R., Sun, J., Bo, Y., Khattak, W. A., Khan, A. A., Jin, C., Zeb, U., Ullah, N., Abbas, A., Liu, W., Wang, X., Khan, S. M., & Du, D. (2024). Understanding the Influence of Secondary Metabolites in Plant Invasion Strategies : A Comprehensive Review. *Plants*, *13*, 1–34.

Allouzi, M.M.A., Allouzi, S.M.A.,Keng, Z.X., Supramaniam, C.V., Singh, A., & Chong, S. (2022). Liquid biofertilizers as a sustainable solution for agriculture. *Heliyon*, *8*(12), e12609. https://doi.org/https://doi.org/10.1016/j.heliyon.2022.e12609

ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

Alobwede, E. Leakebe, J.R. & Pandhal, J (2019). This is a repository copy of Circular economy fertilization : Testing micro and macro algal species as soil improvers and nutrient sources for crop production in greenhouse and field cndition. *Geoderma*, *334*, 113–123.

Amin, M. E.-M. H. (2011). Effect of different nitrogen sources on growth, yield and quality of fodder maize (Zea mays L.). *Journal of the Saudi Society of Agricultural Sciences*, *10*(1), 17–23. https://doi.org/https://doi.org/10.1016/j.jssas.2010.06.003

Anh, N. H., Phat, C. T., Nhut, L. M., Thu, L. T. M., Trong, N. D., Quang, L. T., Xuan, L. N. T., Nhan, T. C., Phong, N. T., & Khuong, N. Q. (2025). Effectiveness of Nitrogen-Fixing Bacteria Rhodobacter sphaeroides in Soil – Plant Nitrogen and Rice Performance in Extremely Saline Acid Sulfate Soil over Two Consecutive Seasons. *Sustainability*, *17*, 1–19.

Anli,M., Marouane, B., Abdelilah, T., Anas, R., Sarah,S., Abderrahim,B., Ait-El-Mokhtar., Ben-Laouane, Raja., Salma, T., Youssef, A.R., Mustapha, A.C., Khalid, O., Toshiaki, M., Mohamed, H., & Abdelilah, M. (2020). Biofertilizers as Strategies to Improve Photosynthetic Apparatus, Growth, and Drought Stress Tolerance in the Date Palm. *Frontiers in Plant Science*, *Volume 11-2020*. https://doi.org/10.3389/fpls.2020.516818

Bishnu Maya, K.C.B., Gauchan, D.P., Khanal, S.N., Chimouriya, S., & Lamichhane, J. (2021). Amelioration of growth attributes of Bambusa nutans subsp. cupulata Stapleton by indole-3-acetic acid extracted from newly isolated Bacillus mesonae MN511751 from rhizosphere of Bambusa tulda Roxburgh. *Biocatalysis and Agricultural Biotechnology*, *31*, 101920. https://doi.org/https://doi.org/10.1016/j.bcab.2021.101920.

Badan Pusat Statistik Purbalingga. (2026). Produksi Jagung Menurut Kecamatan di Kabupaten Purbalingga. https://purbalinggakab.bps.go.id/id/statistics-table/2/ODgjMg==/produksi-jagung.html Badan Pusat Statistik Purbalingga.

Buleti, S.I., Kuyah, S., Olagoke, A., Gichua, M., Were, S., Chidawanyika,F., & Martin, E.A. (2023). Farmers' perceived pathways for further intensification of push-pull systems in Western Kenya. *Frontiers in Sustainable Food Systems*, *7*(August), 1–14. https://doi.org/10.3389/fsufs.2023.1191038

Cardarelli, M., & Cecchetti, V. (2014). Auxin polar transport in stamen formation and development: How many actors? *Frontiers in Plant Science*, *5*(JUL), 1–13. https://doi.org/10.3389/fpls.2014.00333

Cárdenas, D. (2019). The Cartagena Declaration and the Sustainable Development Goals. *Revista de Nutrición Clínica y Metabolismo*, *2*, 76–81.

Chaudhry, A., Chen, Z. & Gallavotti, A. (2024). Hormonal influence on maize inflorescence development and reproduction. *Plant Reproduction*, *37*(4), 393–407. https://doi.org/10.1007/s00497-024-00510-0

Chaudhry, S., & Sidhu, G. P. S. (2022). Climate change regulated abiotic stress mechanisms in plants: a comprehensive review. *Plant Cell Reports*, *41*(1), 1–31. https://doi.org/10.1007/s00299-021-02759-5

Chieb, M., & Gachomo, E. W. (2023). The Role Of Plant Growth Promoting Rhizobacteria In Plant Drought Stress Responses. *Springer BMC Plant Biology*, *23*, 1–23.

De Long,J.R., Heinen,R., Heinze,J., Morriën, E., Kenny Png,G., Sapsford, S.J., François, P., Teste., & Fry, E. L. (2023). Plant-soil feedback: incorporating untested influential drivers and reconciling terminology. *Plant and Soil*, *485*(1), 7–43. https://doi.org/10.1007/s11104-023-05908-9

Dong, X.,Li, B., Yan, Z., Guan, L., Huang, S., Li, S., Qi, Z., Tang, L., Tian, H., Fu, Z., & Yang, H. (2024). Impacts of high temperature, relative air humidity, and vapor pressure deficit on the seed set of contrasting maize genotypes during flowering. *Journal of Integrative Agriculture*, *23*(9), 2955–2969. https://doi.org/https://doi.org/10.1016/j.jia.2023.09.007

ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

Duran-Lara, E.F., Valderrama, A., & Marican, A. (2020). Natural organic compounds for application in organic farming. *Agriculture (Switzerland)*, *10*(2), 1–22. https://doi.org/10.3390/agriculture10020041

Dursun, A., Yildirim, E., Turan, M., Ekinci, M., Kul,R., & Karagoz,F.P. (2019). Determination of the effects of bacterial fertilizer on yield and growth parameters of tomato. *Journal of Agricultural Science and Technology*, *21*(5), 1227–1234.

Etesami, H. (2025). The dual nature of plant growth-promoting bacteria: Benefits, risks, and pathways to sustainable deployment. *Current Research in Microbial Sciences*, *9*, 100421. https://doi.org/https://doi.org/10.1016/j.crmicr.2025.100421

Evans, C. C., & Qaderi, M. M. (2024). Supplemental nitrogen alleviates the negative effects of higher temperature on the vegetative growth of canola regardless of carbon dioxide concentration. *Plant Stress*, *13*, 100521. https://doi.org/https://doi.org/10.1016/j.stress.2024.100521.

George, D.M., Vincent, A.S., & Mackey, H.R. (2020). An overview of anoxygenic phototrophic bacteria and their applications in environmental biotechnology for sustainable Resource recovery. Biotechnology Report. (28):1-20.

Grosso, G., Mateo, A., Rangelov, N., Buzeti, T., & Birt, C. (2020). Nutrition in the context of the Sustainable Development Goals. *European Journal of Public Health*, *30*(1), 19–23. https://doi.org/10.1093/eurpub/ckaa034

Gugissa, D.A., Abro, Z., & Tefera, T. (2022). Achieving a Climate-Change Resilient Farming System through Push–Pull Technology: Evidence from Maize Farming Systems in Ethiopia. *Sustainability (Switzerland)*, *14*(5). https://doi.org/10.3390/su14052648

Gunaseelan, K., Sugumar, M., & Gajalakshmi, S. (2024). An Overview of Photosynthetic Bacteria-Based Microbial Fuel Cells. In *Photosynthesis-Assisted Energy Generation* (pp. 153–175). https://doi.org/https://doi.org/10.1002/9781394172337.ch7

Guo, K., Yang, J., Yu, N., Luo, L., & Wang, E. (2023). Biological nitrogen fixation in cereal crops: Progress, strategies, and perspectives. *Plant Communications*, *4*(2), 100499. https://doi.org/https://doi.org/10.1016/j.xplc.2022.100499

Isah, T. (2019). Stress and defense responses in plant secondary metabolites production. *Biological Research*, *52*(1), 39. https://doi.org/10.1186/s40659-019-0246-3

Jalloh,A.A., Khamis,F.M., Yusuf, A.A., Subramanian,S., & Mutyambai,D.M. (2024). Long-Term Push–Pull Cropping System Shifts Soil And Maize-Root Microbiome Diversity Paving Way To Resilient Farming System. *BMC Microbiology*, *24*(1), 92. https://doi.org/10.1186/s12866-024-03238-z

Kamyab, H., Chelliapan, S., Khalili, E., Rezania, S., Balasubramanian., Taheri, M.M., Simancas-Racines, D., Rajendran, S., & Yusuf, M. (2025). Biochar as a carrier for plant growth-promoting bacteria in phytoremediation of pesticides. *Journal of Hazardous Materials Advances*, *18*, 100673. https://doi.org/https://doi.org/10.1016/j.hazadv.2025.100673

Kurosawa, Rd.N.F., Amaral Júnior,A.Td., Vivas, J,M.S., Vivas, M., Kamphorst,S.H., Jairo de Lima, V. & de Almeida, R. N. (2020). Selection Of Popcorn Hybrids Resistant To Southern Corn Leaf Blight Grown In Distinct N Availability. *European Journal of Plant Pathology*, *158*(2), 485–493. https://doi.org/10.1007/s10658-020-02091-w.

Kushkevych, I., Procházka, V., Vítězová, M., Dordević, D. El-Salam, M. A., & Rittmann, S.K.M.R.(2024).Anoxygenic photosynthesis with emphasis on green sulfur bacteria and a perspective for hydrogen sulfide detoxification of anoxic environments.Frontiers in Microbiology.15:1-20.

Labunskaya, E.A., Voronov,D. A., Lobyshev,V. I., & Krasnova, E. D. (2024). Underwater Measurements of Transmitted Light Spectra in Stratified Reservoirs of the White Sea Coast as a Key to the Understanding of Pigment

ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

Composition of Phototrophs in the Chemocline Zone. *Biophysics*, *69*(3), 533–550. https://doi.org/10.1134/S000635092470060X

Liu, H., Li, H., Wei, H., Zhu, X., Han, D., Jin, J., Yang, Y., & Xie, S. (2019). Biofloc formation improves water quality and fish yield in a freshwater pond aquaculture system. *Aquaculture*, *506*, 256–269. https://doi.org/https://doi.org/10.1016/j.aquaculture.2019.03.031

Liu, M., Zhou, Y., Sun, J., Mao, F., Yao, Q., Li, B., Wang, Y., Gao, Y., Dong,X., Liao, S., Wang, P., & Huang, S. (2023). From the floret to the canopy: High temperature tolerance during flowering. *Plant Communications*, *4*(6), 100629. https://doi.org/https://doi.org/10.1016/j.xplc.2023.100629

Lu, Ha., Zhao, R., Wang, C., Zhang, G., Chen, C., Li, B., & Han, T. (2022). Exploration of flashing light interaction effect on improving biomass, protein, and pigments production in photosynthetic bacteria wastewater treatment. *Journal of Cleaner Production*, *348*, 131304. https://doi.org/10.1016/J.JCLEPRO.2022.131304

Miao, L., Wang, X., Yu, C., Ye, C., Yan, Y., & Wang, H. (2024). What factors control plant height? *Journal of Integrative Agriculture*, *23*(6), 1803–1824. https://doi.org/https://doi.org/10.1016/j.jia.2024.03.058

Moosavi-Nezhad, M. … Aliniaeifard, S. (2022). Growth, Biomass Partitioning, and Photosynthetic Performance of Chrysanthemum Cuttings in Response to Different Light Spectra. *Plants*, *11*, 1–20.

Moreau, D., Ballini, E., Chave, M., Cordeau, S., Djian-Caporalino, C., Anne-Violette, , Suffert, F., & Cortesero, A-M.. (2025). Potential of service plants for regulating multiple pests while limiting disservices in agroecosystems. A review. *Agronomy for Sustainable Development*, *45*(4), 38. https://doi.org/10.1007/s13593-025-01031-4

Mutyambai, D.M., Bass, E., Luttermoser, T., Poveda, K., Midega, C.A.O., Zeyaur, R.K., & Kessler, A. (2019). More than “push” and “pull”? Plant-soil feedbacks of maize companion cropping increase chemical plant defenses against herbivores. *Frontiers in Ecology and Evolution*, *7*(JUN). https://doi.org/10.3389/fevo.2019.00217

Nasution, R.N.S., Warnita., & Zainal, A. (2025). Pengaruh Jenis dan Dosis Pupuk Cair Terhadap Kandungan Klorofil, Serat Kasar dan Vitamin C pada Tanaman Pakcoy secara Hidroponik. *Agroteknika*, *8*(1), 164–178. https://doi.org/10.55043/agroteknika.v8i1.450

Panunggul, V.B., Sitanini, A., Putranto, A.F.,Widodo, S.G., & Panjaitan, E.A.P.. (2023). Pengaruh Pupuk Kandang dan Bakteri Fotosintesis Terhadap Pertumbuhan dan Hasil Tanaman Kale (Brassica oleracea L. Var. Acephala). *Agrika: Jurnal Ilmu-Ilmu Pertanian*, *17*(November), 220–231.

Prasanna,B.M., Cairns, J.E., Zaidi, P.H. Beyene,Y., Makumbi, D. Gowda,M., Magorokosho, C., Zaman-Allah,M., Olsen, M., Aparna Das, Worku,M., Gethi,J., Vivek, B.S., Nair, S.K., Rashid, Z., Vinayan, M.T., Issa,A.B., Vicente, F.S., Dhliwayo, T., & Zhang, X. (2021). Beat The Stress : Breeding For Climate Resilience In Maize For The Tropical Rainfed Environments Climate Resilient Maize For Asia Heat Tolerant Maize For Asia Improved Maize For Tropical Asia International Institute Of Tropical Agriculture. *Theoretical and Applied Genetics*, *134*(6), 1729–1752. https://doi.org/10.1007/s00122-021-03773-7

Shaji, H., Chandran, V., & Mathew, L. (2021). Chapter 13 - Organic fertilizers as a route to controlled release of nutrients. In F. B. Lewu … R. B. T.-C. R. F. for S. A. K.R. (Eds.), *Academic Press* (pp. 231–245). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-819555-0.00013-3

Six, A., Dimitriades-Lemaire, A.., Lancelon-Pin, C., Putaux,J.-L., Dauvillée, D., Petroutsos, D., Alvarez Diaz, P., Sassi, J.-F., Beisson, Y. Li., & Fleury, G. (2024). Red light induces starch accumulation in Chlorella vulgaris without affecting photosynthesis efficiency, unlike abiotic stress. *Algal Research*, *80*, 103515. https://doi.org/https://doi.org/10.1016/j.algal.20

ISSN: 2597-6702 (PRINT)
ISSN: 2622-2272 (ONLINE)

24.103515

Sun, W., Shahrajabian, M.H., Soleymani, A. (2024). The Roles of Plant-Growth-Promoting Rhizobacteria (PGPR)-Based Biostimulants for Agricultural Production Systems. *Plants*, *13*(5), 1–37. https://doi.org/10.3390/plants13050613

Wang, Y., Peng, S., Hua, Q., Qiu, C., Wu, P., Liu.X.,& Lin, X. (2021). The Long-Term Effects of Using Phosphate-Solubilizing Bacteria and Photosynthetic Bacteria as Biofertilizers on Peanut Yield and Soil Bacteria Community. *Frontiers in Microbiology*, *12*, 1–14. https://doi.org/10.3389/fmicb.2021.693535

Wang, Y., Pei, Y., Wang, X., Dai, X., & Zhu, M. (2024). Antimicrobial metabolites produced by the plant growth-promoting rhizobacteria (PGPR): Bacillus and Pseudomonas. *Advanced Agrochem*, *3*(3), 206–221. https://doi.org/https://doi.org/10.1016/j.aac.2024.07.007

Wang, Z., Gao, D., Zhan, Y., & Xing, C. (2020). Enhancing the Light Coverage of Photosynthetic Bacteria to Augment Photosynthesis by Conjugated Polymer Nanoparticles. *ACS Applied Bio Materials*, *3*(5), 3423–3429. https://doi.org/10.1021/acsabm.0c00352

Yang,H., Liu, J., Ma, M., Tan, Z., Zhang, K., Sun, R., Zhan, X., & Cui, D. (2025). Leaf Development and Its Interaction with Phyllospheric Microorganisms: Impacts on Plant Stress Responses. *Plant Stress*, *16*, 100843. https://doi.org/https://doi.org/10.1016/j.stress.2025.100843

Zhang, X., Wu,J., & Kong, Z. (2024). Cellular basis of legume–rhizobium symbiosis. *Plant Communications*, *5*(11), 101045. https://doi.org/https://doi.org/10.1016/j.xplc.2024.101045