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Bioprospecting of Selected *Trichoderma* spp. for Its Plant Growth Promoting and Biocontrol Properties

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Abstract: Bioprospecting for *Trichoderma* strains from peat soil collected at MARDI Sessang Station, Saratok, Sarawak, revealed promising candidates as plant growth-promoting microbes (PGPM) and producers of phytohormones such as indole-3-acetic acid (IAA) and gibberellic acid (GA₃). The study aimed to identify *Trichoderma* strains with dual functions in biocontrol and plant growth enhancement. A total of seventeen strains were isolated and screened for their biocontrol activity against significant plant pathogens—*Ralstonia solanacearum* and *Colletotrichum gloeosporioides* and also their potential to produce IAA and GA₃. Among the isolates, one strain exhibited strong antagonistic activity against *R. solanacearum*, a pathogen responsible for bacterial wilt, suggesting its potential for biocontrol applications. Additionally, two strains showed significant inhibitory effects against *C. gloeosporioides*, the causative agent of anthracnose. Four strains demonstrated the ability to produce IAA, an essential auxin for root development and overall plant growth promotion and two strains were identified as GA₃ producers, contributing to plant growth by promoting cell elongation and germination. This study highlights the potential of *Trichoderma* strains from peat soils in Sarawak as valuable resources for sustainable agriculture. The dual functionality of these strains as biocontrol agents and phytohormone producers makes them promising candidates for integrated pest management (IPM) and biofertilizer development. Future research should focus on field trials and further molecular characterization to fully explore the potential of these *Trichoderma* isolates in enhancing crop productivity.

Keywords: Biological control, green technology, organic agriculture, plant pathogens, white agriculture.

1.0 Introduction

The increasing global demand for sustainable agricultural practices has led to a heightened focus on the use of biocontrol agents and plant growth-promoting microbes (PGPM) as alternatives to chemical pesticides and fertilizers. Among the various microbial agents, *Trichoderma* species stand out for their ability to enhance plant growth and combat a wide range of plant pathogens. Recent research has highlighted the potential of *Trichoderma* strains not only as biocontrol agents but also as producers of plant growth-promoting phytohormones such as indole-3-acetic acid (IAA) and gibberellic acid (GA₃) (Tyśkiewicz et al., 2022). Bioprospecting for new strains of *Trichoderma* from underexplored environments, such as peat soils, is essential to discover novel microbes with enhanced or unique functional traits that can address current agricultural challenges.

Peat soils, characterized by their high organic matter content and moisture, serve as a rich reservoir of microbial diversity. In tropical regions like Sarawak, Malaysia, where these soils are abundant, the microbial communities adapted to these environments may hold untapped potential for agricultural applications (Too et al., 2018). The unique properties of peat soil, including its acidic pH and high organic carbon, could foster the development of *Trichoderma* strains with specialized traits that are particularly suited to combating pathogens and promoting plant growth in challenging agricultural conditions.

The current study focuses on isolating *Trichoderma* strains from peat soil to target two critical plant pathogens: *Ralstonia solanacearum* and *Colletotrichum gloeosporioides*. *R. solanacearum* is considered important because it is the world's second most damaging phytopathogen (Wang et al., 2023). This pathogen thrives in warm, moist environments, making it a significant threat to tropical agriculture. On the other hand, *C. gloeosporioides* is responsible for anthracnose,

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a widespread fungal disease that affects fruit, and vegetable globally, leading to severe yield losses (Peralta-Ruiz et al., 2023). Identifying *Trichoderma* strains with strong antagonistic activity against these pathogens could provide a sustainable solution for managing these diseases, especially in regions where chemical controls are either ineffective or environmentally damaging.

In addition to biocontrol properties, certain *Trichoderma* strains are known to produce phytohormones such as indole-3-acetic acid and gibberellic acid, which play pivotal roles in promoting plant growth. IAA, a key auxin, regulates processes such as root elongation, cell division, and differentiation, thereby enhancing nutrient uptake and overall plant health. Gibberellin is crucial for seed germination, stem elongation, and flowering, further contributing to improved crop productivity. The ability of *Trichoderma* to produce these phytohormones highlights its potential as a biofertilizer, offering an eco-friendly alternative to chemical fertilizers that can enhance crop yields and support sustainable farming practices.

This study aims to bioprospect *Trichoderma* strains from peat soil at MARDI Sessang Station, Saratok, Sarawak, to identify strains with dual functions: biocontrol activity against *R. solanacearum* and *C. gloeosporioides*, and the production of IAA and GA3 which might be useful for the development of integrated pest management (IPM) systems.

2.0 Materials and methods

2.1 Isolation of *Trichoderma* spp. From Soil

Trichoderma spp. was isolated from virgin peat soil collected at MARDI Sessang Station, Saratok, Sarawak, with coordinates 1.92632 latitude and 111.23722 longitude. The soil samples were placed in double zip-lock bags for transport to the laboratory. Upon arrival, 10 g of soil was weighed and added to a 250 mL Erlenmeyer flask containing 100 mL of sterile distilled water, then agitated for 1 hour at 250 rpm. After agitation, 150 μ L of the soil suspension was pipetted onto a fresh Potato Dextrose Agar (PDA) plate, which was incubated at room temperature ($28 \pm 2^\circ\text{C}$) for 7 days. The emerging *Trichoderma* spp. was cut at the edge of the colony and placed onto a fresh PDA.

2.2 Screening for antibacterial activity against *Ralstonia solanacearum*

Trichoderma spp. was cultured on PDA for 7 days. *Ralstonia solanacearum* (MMCC10070) was sourced from the MARDI Microbial Culture Collection (MMCC) and grown on Tetrazolium Chloride Agar (TZC) for 24-48 hours. Once the colonies developed, an antimicrobial test was conducted using the agar diffusion method. *R. solanacearum* was spread on fresh TZC agar, and a plug of *Trichoderma* spp. with the size of 5 mm was placed on the agar surface. Test was conducted in triplicate. The appearance of a clear zone after 24 hours indicated the antimicrobial activity of *Trichoderma* spp. (Figure 1). Percentage of inhibition was calculated based on the formula:-

$$\text{PI} = [(I_z - \text{Trt}) / I_z] \times 100\%$$

PI: Percent inhibition (%),

I_z : Diameter growth of inhibition zone (mm)

Trt: *Trichoderma* spp. plug size (mm)

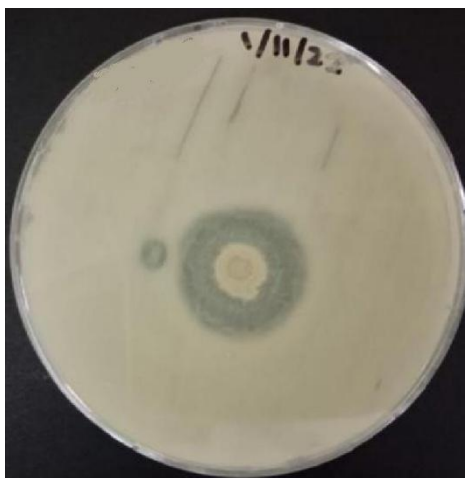


Fig. 1: Antibacterial activity of *Trichoderma* spp. against *Ralstonia solanacearum*

2.3 Screening for antifungal activity against *Colletotrichum gloeosporioides*

Trichoderma spp. was cultivated on PDA for 7 days. *Colletotrichum gloeosporioides* (MMCC20013) was sourced from the MARDI Microbial Culture Collection (MMCC) and also grown on PDA for 7 days. Once pure fungal colonies were

visible, plugs of *Trichoderma* spp. and *C. gleosporioides* were positioned next to each other in a dual plug antagonist assay (Figure 2). Test was conducted in triplicate. The appearance of a clear zone indicated antifungal activity between *Trichoderma* spp. and *C. gleosporioides*. Percentage of inhibition was calculated based on the formula:-

$$PI = [(Cr1 - Trt) / Cr1] \times 100\%$$

PI: Percent inhibition (%),

Cr1: Radial growth of the control *Colletotrichum gleosporioides* (mm),

Trt: Radial growth of *Colletotrichum gleosporioides* with *Trichoderma* spp. (mm)



Fig. 2: Dual culture antagonistic between *Trichoderma* spp. and *Colletotrichum gleosporioides*

2.4 Screening for indole-3-acetic acid (IAA) production

The procedure for producing Indole-3-Acetic Acid (IAA) was adapted from the research of Iqbal and Hasnain (2013) with minor adjustments. Fungal cell suspensions were maintained at a temperature of $30 \pm 2^\circ\text{C}$ for 48 hours, and the density of the culture broth was calibrated to 10^6 cfu/mL using a hemacytometer. Then, 2 mL of the culture broth were transferred to a fresh Eppendorf tube and centrifuged at 10,000 rpm for 30 minutes. After centrifugation, the supernatant was combined with Salkowski's reagent in a 2:1 ratio and incubated in the dark for 30 minutes. The appearance of a pink color confirmed the production of IAA by *Trichoderma* spp. A standard curve was created using synthetic IAA (Sigma), samples were analyzed at 520 nm using a Nanodrop spectrophotometer.

2.5 Screening for gibberellic acid (GA₃) production

The screening for GA₃ production by *Trichoderma* spp. was performed following the protocol established by Pandya and Desai (2014). A standard curve was created using synthetic GA₃ (Sigma), samples were analyzed at 254 nm using a Nanodrop spectrophotometer.

2.6 Identification of *Trichoderma* spp. using molecular method

Genomic DNA from *Trichoderma* spp. was isolated using the QIAamp® DNA Mini Kit, following the protocol provided by Qiagen (Qiagen 2020). Polymerase chain reaction (PCR) was then performed using ITS primers. The reaction mixture had a final volume of 25 µL, containing 0.1 µg of genomic DNA, 10 pM of each primer (ITS4 and ITS5), $1 \times$ Taq polymerase buffer, 1.5 mM MgCl₂, 0.2 mM dNTPs, and 1 U of Taq DNA polymerase. The thermal cycling conditions included an initial denaturation at 94°C for 3 minutes, followed by 35 cycles of 94°C for 30 seconds, 55°C for 40 seconds, and 72°C for 35 seconds, with a final extension at 72°C for 7 minutes (Lu et al. 2012). The PCR products were purified using the QIAquick PCR Purification Kit (Qiagen 2020) and sent for sequencing to Apical Scientific Sdn. Bhd., Selangor. The sequencing results were then compared with the National Center for Biotechnology Information (NCBI) database.

3. Results

3.1 Isolation of *Trichoderma* spp. and screening of antibacterial and antifungal activities

From the sample of peat soil collected from the virgin peat soil it was observed that 17 isolates of *Trichoderma* spp. were isolated. Each *Trichoderma* spp. was tested for their individual ability to produce antibacterial and antifungal activity. It was noted from the result that only *Trichoderma* spp. Ps1 inhibited the growth of *Ralstonia solanacearum* while *Trichoderma* spp. Ps 9 and *Trichoderma* spp. Ps 15 inhibited the growth of *Colletotrichum gleosporioides* (Table 1).

3.2 Screening of indole-3-acetic acid (IAA) and gibberellic acid (GA₃)

Screening of phytohormones production indicated that 4 isolates and 2 isolates of *Trichoderma* spp. were able to produce IAA and GA₃, respectively. *Trichoderma* spp. Ps 1, *Trichoderma* spp. Ps 5, *Trichoderma* spp. ps 8 and *Trichoderma* spp. Ps 10 were observed to be IAA producer while *Trichoderma* spp. Ps 3 and *Trichoderma* spp. Ps 4 were identified as GA₃ producer (Table 1).

Table 1: Antibacterial, antifungal activities and phytohormone production of isolated *Trichoderma* spp.

Isolate no.	Antibacterial and antifungal activities (average % inhibition \pm SD %)		Phytohormone production (average \pm SD μ g/mL)	
	<i>Ralstonia</i>	<i>Colletotrichum</i>	IAA	GA ₃
	<i>solanacearum</i>	<i>gleosporioides</i>		
Ps 1	66.7 \pm 0.76	-	9.07 \pm 0.231	-
Ps 2	-	-	-	-
Ps 3	-	-	-	18.9 \pm 0.666
Ps 4	-	-	-	-
Ps 5	-	-	4.30 \pm 0.200	-
Ps 6	-	-	-	-
Ps 7	-	-	-	-
Ps 8	-	-	8.13 \pm 0.153	-
Ps 9	-	68.5 \pm 0.76	-	-
Ps 10	-	-	6.17 \pm 0.153	-
Ps 11	-	-	-	-
Ps 12	-	-	-	-
Ps 13	-	-	-	-
Ps 14	-	-	-	-
Ps 15	-	81.5 \pm 0.29	-	15.4 \pm 0.321
Ps 16	-	-	-	-
Ps 17	-	-	-	-

3.3 Identification of *Trichoderma* spp.

The 3 *Trichoderma* spp. with antibacterial and antifungal activities were identified using molecular method. Result of the sequencing showed that all the 3 isolates were *Trichoderma harzianum*, *Trichoderma* spp. and *Trichoderma viride* (Table 2).

4.0 Discussion

The isolation of soil *Trichoderma* spp. with biological activities was not something new. The potential of *Trichoderma* species as biological plant protection agents was first described in the early 1930s by Weindling (1932), where he observed that the *T. lignorum* strain having antagonistic activity against *Rhizoctonia solani*. Researchers around the world had then embark in the research of bioactivity from *Trichoderma* spp. against other plant pathogens such as *Ralstonia solanacearum*, *Botrytis cinerea*, *Fusarium graminearum*, *Penicillium expansum*, and *Ganoderma* (De Zotti et al., 2020; Yendyo et al., 2017; and Supriyanto et al., 2020). In a study conducted by Xue et al. (2020), the researchers observed that *Trichoderma* spp. isolated showed high percentage of inhibition activity against *Colletotrichum gleosporioides* (85 – 97%) compared to our study of only 68 – 81%. Adrian Barbosa et al. (2022), noted that antimicrobial activity between *C. gleosporioides* and *Trichoderma* isolated from yam plantation showed inhibition zones ranging from 81 – 92 % which is not much different if compared to the results we obtained in this study. Satapathy and Beura (2020), showed that *Trichoderma viride* has the potential to produce antifungal activity against *C. gleosporioides* with the percentage of inhibition at 84.9%. In this study we also observed that *T. viride* has the highest percentage of inhibition that is 81%, this might indicate that *T. viride* is a potent antifungal producer. Antimicrobial activity of *Trichoderma* spp. against *Ralstonia solanacearum* was also well studied. A recent study stated that, inhibition of *Trichoderma* versus *R. solanacearum* was observed to be at 71%. This result was not too different from what we observed in our study (66.7%). Study done by Rahman et al. (2023) indicated that *T. harzianum* used in their study was able to exhibit 51% inhibition towards *R. solanacearum*. This showed that *T. harzianum* Ps 1 used in this study have comparable efficacy to *T. harzianum* used in Rahman et al. (2023) study.

Trichoderma spp. isolated by Akbari et al. (2024), showed the highest production of IAA at 63.91 μ g/mL, this reading is much higher than the reading that we observed from our *Trichoderma* spp. which is only 9.07 μ g/mL. Apart from that *Trichoderma* TM10 isolated by Akbari et al. (2024) also showed much higher IAA production of 63.91 μ g/mL which is about 7 times higher than our finding. For the production of GA₃, Lakhdari et al. (2022) observed that *T. harzianum* S2 gave the highest GA3 content of 83 mg/L. However, Ruikar et al. (2024) noted that *T. harzianum* used in

their study only produce 35 µg/mL of GA₃. This showed that the current *Trichoderma* isolated from this study are potential IAA and GA₃ source but might not be as good as *Trichoderma* isolated by other researchers. However, by combining the potential of biocontrol shown by these *Trichoderma* spp. together with their ability to produce IAA and GA₃, we can produce a potential biopesticide which has the added benefit of plant growth promoting ability.

Table 2: Genetic Sequences and Identification of Three Potential *Trichoderma* Isolates

Isolate no.	Id	Sequence	Percent identity (%)	E- value
Ps 1	<i>Trichoderma harzianum</i>	cggttggtgaa ccagcggagg gatcattacc gagtttaca cccccaaacc caatgtgaac gttaccaaac tgttgccctcg gcgggatctc tgccccgggt gcgtgcgagc cccggacca ggcgcccgcc ggaggacca ccaaaactct tattgtatac ccctcgcgg gtttttact atctgagcca agagccgcgg cctcgtgggc gtttcgaaa ggaagcaaaa ctttcaacaa cggatctctt ggttcggca tcgatgaaga acgcagcgaa atgcgataag taatgtgaat tgcagaattc aacgcacatt gcgcccgcca gtattctggc gggcatgcct gtccgagcgt cattcaacc ctgaacccc tccggggggg cggcgttggg gatcggccct ttacggggcc ggccccgaaa tacagtggcg gtctcgccgc agcctctct ggcagtagt ttgcacact gcacgggag cgcggcgct ccacagccgt aaactctga aatgttgacc taggaatacc	94.4	0.0
Ps 9	<i>Trichoderma</i> spp.	caatccaaac tgttgccctcg gcgggatctc tgccccgggt gcgtgcgagc cccggacca ggcgcccgcc ggaggacca ccaaaactct tattgtatac cgctcgcgg gttttttat aatctgagcc ttctcgccgc ctctcgtagg cgtttcgaaa atgaatcaaa actttcaaca acggatctct tggttcggc atcgatgaag aacgcagcga gtaatgtgaa tgcagaatt cagtgaatca tcgaatctt gaacgcacat tgcgccgcc agtattctgg cggcatgcc tgtccgagcg tcattcaac cctgaaccc ctccgggggg tcggcgttgg ggatcgccc tgccttggcg gtggccgtct ccgaataca gtggcgtct cgccccagcc tctctgcgc actagtgtgc acactcgcat cgggagcgag gcccgtccaa ggccataaat caccacaaat ctgagatgtg	97.8	0.0
Ps 15	<i>Trichoderma viride</i>	gggatcatta ccgagtttac aactccaaa ccaatgtga accatacaca actgttcct cggcgggggc acgccccggg tgcgtcgag ccccggaacc aggcgccgc cggagggacc aacaaactc ttctgtagt ccctcgcgg acgttaattt tacagctctg agcaaaaatt caaatgaat caaaacttc aacaacggat ctcttggtc tggcatgat gaagaacgca gcgaaatgcg ataagtaatg tgaattgcag aattcagtga atcatcgaat cttgaacgc acattgcgc cgcagtagt ctggcgggca tgcctgtccg agcgtcatt caaccctga acccctcgg ggggtcggcg ttggggactt cgggaacccc taagacggga tcccggcccc gaaatacagt ggcggtctcg cgcagcctc tcattgcgag tagtttcac aactcgacc gggagcgcgg cgcgtccacg tccgtaaaac acccaactc tgaatgttg acctcgatc agg	100.0	0.0

5.0 Conclusion

This study highlights the potential of *Trichoderma* sp isolated from peat soil. *Trichoderma harzianum* Ps1 and *Trichoderma viride* Ps15 isolated from peat soil showed the ability to be used as biological control agents for *Ralstonia solanacearum* and *Colletotrichum gleosporioides* with the percentage of inhibition zone of 66% and 81% respectively. *Trichoderma harzianum* Ps1 and *Trichoderma* sp PS 3 showed the ability to produce IAA and GA₃ at 9.07 and 18.9 µg/mL respectively. Utilization of microbial products for agriculture will help to reduce usage of chemicals which will be detrimental not just for human but also planetary health.

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Conflict of Interest

The authors declare no conflicts of interest.

References

- Akbari, S.I., Prismantoro, D., Kusmoro, J., Hasan, R., Nurzaman, M., Rossiana, N. & Doni, F. (2024). Isolation, screening, and molecular characterization of indigenous *Trichoderma* isolates from West Java, Indonesia and their plant growth-promoting capability on rice plants (*Oryza sativa* L.). *Journal of King Saud University - Science*, 36(9), 103378. <https://doi.org/10.1016/j.jksus.2024.103378>
- Adrian Barbosa, G., Alexander, P.C., Donicer, E. & Montes, V. (2022). Plant Growth Promoting Activity of *Trichoderma* Spp. and its Potential Biocontrol Against *Colletotrichum Gloesporioides*. *Journal of Namibian Studies : History Politics Culture*, 32, 239-256. <https://doi.org/10.59670/jns.v32i.2752>
- De Zotti, M., Sella, L., Bolzonello, A., Gabbatore, L., Peggion, C., Bortolotto, A., Elmaghraby, I., Tundo, S. & Favaron, F. (2020). Targeted amino acid substitutions in a *Trichoderma* peptaibol confer activity against fungal plant pathogens and protect host tissues from *Botrytis cinerea* infection. *International Journal of Molecular Sciences*, 21:7521. <https://doi.org/10.3390/ijms21207521>
- Iqbal, A. & Hasnain, S. (2013). Auxin producing *Pseudomonas* strains: Biological candidates to modulate the growth of *Triticum aestivum* beneficially. *American Journal of Plant Sciences*, 4, 1693-1700.
- Lakhdari, W., Azher, A., Mlik, R., Benyahia, I., Mekhadmi, N.E., Guezoul, O., Hammi, H & Dehliz, A. (2022). Gibberellin production by antagonistic fungus strains (*Trichoderma harzianum*). *Revue des BioRessources*, 12 (2):74-81.
- Pandya, N.D. & Desai, P.V. (2014). Screening and characterization of GA3 producing *Pseudomonas monteilii* and its impact on plant growth promotion. *International Journal of Current Microbiology and Applied Sciences*, 3(5), 110-115.
- Peralta-Ruiz, Y., Rossi, C., Grande-Tovar, C. D., & Chaves-López, C. (2023). Green Management of Postharvest Anthracnose Caused by *Colletotrichum gloeosporioides*. *Journal of Fungi*, 9(6). <https://doi.org/10.3390/jof9060623>
- Rahman, M., Borah, S.M., Borah, P.K., Bora, P., Sarmah, B.K., Lal, M.K., Tiwari, R.K., & Kumar, R. (2023). Deciphering the antimicrobial activity of multifaceted rhizospheric biocontrol agents of solanaceous crops viz., *Trichoderma harzianum* MC2, and *Trichoderma harzianum* NBG. *Frontiers in Plant Science*, 14:1141506. <https://doi.org/10.3389/fpls.2023.1141506>
- Ruikar, S., Mulla, M.N & Pathade, G. (2024). Isolation and characterization of indole acetic acid, gibberellic acid producing, and phosphate solubilizing microorganisms from rhizosphere and endosphere of Entacloo hasnahana. *Bulletin of Pure and Applied Sciences Zoology (animal Science)*. 24B(1):273-286.
- Satapathy, R.R. & Beura, S.K. (2020). Management of *Colletotrichum gloeosporioides* (Penz.) causing cashew anthracnose through bio-control agents. *Journal of Pharmacognosy and Phytochemistry*, 9(1):2225-2227.
- Supriyanto, Purwanto, Poromarto, S.H & Supyani. (2020). Evaluation of in vitro antagonistic activity of fungi from peatlands against *Ganoderma* species under acidic condition. *Bioversitas*. 21(7): 2935 – 2945.
- Too, C. C., Keller, A., Sickel, W., Lee, S. M., & Yule, C. M. (2018). Microbial Community Structure in a Malaysian Tropical Peat Swamp Forest: The Influence of Tree Species and Depth. *Frontiers in Microbiology*, 9, 410666. <https://doi.org/10.3389/fmicb.2018.02859>
- Tyśkiewicz, R., Nowak, A., Ozimek, E. & Jaroszuk-Ścisł, J. (2022). *Trichoderma*: The Current Status of Its Application in Agriculture for the Biocontrol of Fungal Phytopathogens and Stimulation of Plant Growth. *International Journal of Molecular Sciences*, 23(4). <https://doi.org/10.3390/ijms23042329>
- Wang, Z., Luo, W., Cheng, S., Zhang, H., Zong, J., & Zhang, Z. (2023). *Ralstonia solanacearum* – A soil borne hidden enemy of plants: Research development in management strategies, their action mechanism and challenges. *Frontiers in Plant Science*, 14. <https://doi.org/10.3389/fpls.2023.1141902>
- Weindling, R. (1932). *Trichoderma lignorum* as a parasite of other soil fungi. *Phytopathology*. 22:837–845.

Xue, M., Wang, R., Zhang, C., Wang, W., Zhang, F., Chen, D., Ren, S., Manman, Z., Hou, J. & Liu, T. (2020). Screening and identification of *Trichoderma* Strains isolated from natural habitats in China with potential agricultural applications. *BioMed Research International*, 2021(1), 7913950. <https://doi.org/10.1155/2021/7913950>

Yendyo, S, Ramesh, G.C., Pandey, B.R. (2017). Evaluation of *Trichoderma* spp., *Pseudomonas fluorescens* and *Bacillus subtilis* for biological control of *Ralstonia* wilt of tomato. *F1000 Research*, 6:2028. <https://doi.org/10.12688/f1000research.12448.1>.