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Management of wilt disease in cucumber (*Cucumis sativus* L.) using IDM modules

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Abstract— *Wilt caused by Fusarium oxysporum f. sp. cucumerinum is a serious soil-borne disease of cucumber (Cucumis sativus L.) that causes major yield losses, particularly under continuous cultivation. A survey conducted in the Coimbatore region during 2024–2025 revealed wide variation in wilt incidence across locations, ranging from 4.70 to 80.13%. Four integrated disease management (IDM) modules were evaluated under field conditions during 2025 and 2026. Among them, Module 2, comprising soil application and seed treatment with a Trichoderma asperellum + Bacillus subtilis consortium and soil drenching with B. subtilis along with clove oil EC formulation (0.1%), recorded the lowest wilt incidence and the highest yield in both years. In 2025, Module 2 recorded 7.72% wilt incidence at 75 days after sowing (DAS), a yield of 9.00 t/ha and a B:C ratio of 2.92; and in 2026 the corresponding values were 15.40%, 9.32 t/ha and 2.95. Pooled analysis confirmed Module 2 as the best treatment (11.60% wilt incidence, 9.20 t/ha yield and B:C ratio of 2.90) compared with 47.30% wilt incidence and 5.90 t/ha yield in the untreated control. The study showed that a bio-intensive IDM module can manage cucumber wilt effectively under field conditions and is an eco-friendlier alternative to sole dependence on chemicals.*

Keywords— Cucumis sativus, wilt disease, Fusarium, integrated disease management, clove oil, carbendazim, biological control.

I. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an important vegetable crop cultivated widely for its economic and nutritional value, but its productivity is constrained by several fungal, bacterial, and viral diseases (Brar *et al.*, 2025; Yang *et al.*, 2024; Ta *et al.*, 2024; Daunde *et al.*, 2020). Among these, wilt disease is one of the most destructive problems in cucumber production and is commonly associated with *Fusarium oxysporum* f. sp. *cucumerinum*, although other *Fusarium* species can also be involved in some production systems (Brar *et al*., 2025; Din *et al*., 2020). The pathogen is soil-borne, spreads through infested soil and water, infects plants at different growth stages, colonizes vascular tissues and produces symptoms such as damping-off, yellowing of older leaves, vascular browning, wilting and eventual plant death (Din *et al*., 2020; Sharma & Shukla, 2021).

Wilt incidence can be severe under continuous cropping and favorable environmental conditions, with reported yield losses commonly ranging from 10% to 70% and reaching 80% or more in severe infestations (Sharma & Shukla, 2021; Zhu *et al*., 2024; Yang *et al*., 2024; Luo *et al*., 2026). The persistence of chlamydospores in soil for many years and the imbalance of rhizosphere microbial communities contribute to recurring outbreaks and make management difficult (Haridasan & Sajeena, 2025; Yang *et al*., 2024; Yu *et al*., 2024). Conventional control measures such as fungicides, crop rotation, resistant rootstocks, and grafting provide partial relief, but their performance is often limited by environmental concerns, resistance development, unstable host resistance, cost, or operational difficulty (Haridasan & Sajeena, 2025; Brar *et al*., 2025; Yang *et al*., 2024; Yu *et al*., 2024).

For these reasons, integrated disease management has emerged as a more durable strategy for soil-borne diseases because it combines complementary approaches rather than relying on a single tactic (Haridasan & Sajeena, 2025; Mahmood *et al*., 2023; Daunde *et al*., 2020). Biological control agents such as *Trichoderma*, *Bacillus*, *Pseudomonas*, and *Streptomyces* suppress

Fusarium through antagonism, rhizosphere colonization, nutrient competition, and induction of plant defense responses (Wang *et al*., 2021; Zhu *et al*., 2024). Several studies have shown that combined microbial treatments reduce wilt incidence more effectively than single agents and also improve plant growth and yield (Singh & Balodi, 2021; Wang *et al*., 2021; Waris *et al*., 2025; Ta *et al*., 2024).

Botanicals and other eco-compatible inputs can further strengthen disease suppression within IDM systems. Neem-based products, clove oil formulations, silicon, salicylic acid, and other natural or low-risk compounds have been reported to reduce disease severity or enhance host resistance while lowering sole dependence on conventional chemicals (Dey *et al*., 2025; Yu *et al*., 2024; Sun *et al*., 2022; Hussein, 2016). Recent evidence also indicates that integrated modules can improve soil biological activity, microbial balance, and plant physiological resilience in addition to disease control (Luo *et al*., 2026; Yang *et al*., 2024; Sun *et al*., 2022; Tang *et al*., 2020).

Under these conditions, location-specific evaluation of IDM modules is necessary before recommendation to farmers. The present study was therefore undertaken to survey the occurrence of wilt disease in cucumber-growing areas of Coimbatore and to evaluate different IDM modules for suppressing wilt incidence and improving yield and benefit-cost ratio under field conditions.

II. MATERIALS AND METHODS

The study comprised two components: a regional survey on cucumber wilt occurrence in Coimbatore and a field experiment to evaluate IDM modules under natural disease pressure.

2.1 Survey of wilt incidence

Surveys were conducted in major cucumber-growing locations of the Coimbatore region during 2024 and 2025. At each location, wilt incidence was recorded as percent incidence (PI), along with variety, month of survey, and geo-coordinates. Disease surveys are widely used to establish local prevalence and management need in cucumber wilt pathosystems (Din *et al*., 2020).

2.2 Experimental site and design

The field experiment was conducted during 2025 and 2026 in a randomized block design with four treatments and three replications. Similar IDM evaluations in cucumber have commonly used randomized or complete randomized block designs for field assessment of disease incidence and yield (Dey *et al*., 2025).

2.3 IDM treatments

The following four treatments were evaluated (Table 1). The treatment structure was based on the principle that combining cultural sanitation, biological seed or soil application, and targeted root-zone treatment can improve wilt suppression compared with single-method management (Haridasan & Sajeena, 2025; Singh & Balodi, 2021; Mahmood *et al*., 2023; Mouhsan, 2026).

TABLE 1
INTEGRATED DISEASE MANAGEMENT (IDM) MODULES EVALUATED AGAINST CUCUMBER WILT

Module	Components
Module 1	Field sanitation and use of drip irrigation; seed treatment with carbendazim @ 2 g/kg seed; soil drenching with consortia of *Trichoderma asperellum + Bacillus subtilis* @ 0.1% in the root zone at the time of earthing up
Module 2	Soil application of consortia of *Trichoderma asperellum + Bacillus subtilis* @ 2.5 kg/ha; seed treatment with the consortia @ 10 g/kg seed; soil drenching with *Bacillus subtilis* along with clove oil EC formulation 0.1% in the root zone at the time of earthing up
Module 3	Field sanitation and use of drip irrigation; seed treatment with carbendazim @ 2 g/kg seed; soil drenching with carbendazim @ 0.1% in the root zone at the time of earthing up
Module 4 (Control)	No treatment

2.4 Crop protection operations

Seed treatment was imposed before sowing according to the treatment schedule. Soil application or root-zone drenching was carried out at the time of earthing up. Similar studies have used seed treatment, root dipping, root irrigation, or soil drenching

to deliver biological and chemical treatments against cucumber wilt pathogens (Brar *et al*., 2025; Waris *et al*., 2025; Luo *et al*., 2026).

2.5 Observations recorded

Wilt incidence was recorded at 25, 50, and 75 days after sowing (DAS), and fruit yield was recorded at harvest. Disease incidence in cucumber wilt study is typically assessed as the percentage of infected plants, and disease severity can also be graded on 0–4 scales where required (Wang *et al*., 2021; Zhu *et al*., 2024; Ta *et al*., 2024). Benefit-cost ratio was calculated for each treatment to assess economic feasibility, since economic return is a key endpoint in IDM evaluation (Sarkar *et al*., 2025).

2.6 Statistical analysis

The recorded data were subjected to analysis of variance, and treatment means were compared using the critical difference at the 5% probability level. Similar cucumber IDM studies have analyzed treatment effects using ANOVA and mean comparison procedures (Dey *et al*., 2025; Mahmood *et al*., 2023; Ta *et al*., 2024).

III. RESULTS

3.1 Survey on the occurrence of wilt in cucumber

Wilt incidence recorded at 14 locations in the Coimbatore region during 2024 ranged from 9.20 to 80.13% (Table 2). In the subsequent survey, incidence across seven locations ranged from 4.70 to 62.11% (Table 3).

TABLE 2
OCCURRENCE OF WILT DISEASE IN CUCUMBER IN THE COIMBATORE REGION DURING 2024

S. No	Variety	Latitude	Longitude	Month	PI (%)	Location
1	Local	11.017942	77.128062	January	29.12	Sulur, Coimbatore
2	Local	10.857987	76.855707	January	31.25	Navakarai, Coimbatore
3	Local	10.85792	76.85575	January	42.50	Ettimadai, Coimbatore
4	Local	11.0152	76.9326	January	78.35	TNAU, Coimbatore
5	Amaravathi	10.963016	76.845199	March	73.16	Thenkarai, Thondamuthur
6	Local	11.082173	76.883895	March	23.19	Seeranaikenpalayam, Coimbatore
7	Amaravathi	10.8324	77.081831	June	74.67	Kinathukadavu, Coimbatore
8	Local	10.859284	76.855732	July	32.12	Madhukarai, Coimbatore
9	Local	11.0134	76.9536	August	9.20	TNAU, Coimbatore
10	Local	11.0146	76.9324	October	78.34	TNAU, Coimbatore
11	Local	11.082173	76.883895	November	17.14	Seeranaikenpalayam, Coimbatore
12	Local	10.683531	77.048088	December	23.10	Raasakapalayam, Sattakal Pudur, Coimbatore
13	Local	10.820911	76.929427	December	80.13	Coimbatore
14	Local	10.943696	76.79056	December	10.11	Thondamuthur, Coimbatore

TABLE 3
OCCURRENCE OF WILT DISEASE IN CUCUMBER IN THE COIMBATORE REGION DURING 2025

SI. No	Variety	Geo-coordinates	Month of survey	PI (%)	Location
1	Local	10.963016, 76.845199	January	39.30	Thenkarai, Thondamuthur
2	Local	11.0152, 76.9326	February	44.60	TNAU, Coimbatore
3	Local	11.01794, 77.12806	July	45.90	Sulur, Coimbatore
4	Local	10.65504, 76.96938	August	62.11	Pollachi North
5	Local	10.87995, 77.13287	October	12.52	Kinathukadavu
6	Local	11.01794, 77.12806	November	9.21	Sulur, Coimbatore
7	Local	10.65504, 76.96938	December	4.70	Pollachi North

3.2 Field evaluation of IDM modules

3.2.1 First-year field trial (2025)

The first-year trial (2025) showed that Module 2 recorded the minimum disease incidence (7.72% at 75 days after sowing, DAS) and the highest yield (9.00 t/ha) (Table 4). Module 2 comprised soil application of the *Trichoderma asperellum + Bacillus subtilis* consortia @ 2.5 kg/ha, seed treatment with the consortia @ 10 g/kg seed, and soil drenching with *Bacillus subtilis* along with clove oil EC formulation 0.1% in the root zone at the time of earthing up. The control recorded the maximum disease incidence (46.20% at 75 DAS) and the lowest yield (6.13 t/ha).

TABLE 4
EFFECT OF DIFFERENT IDM MODULES ON WILT INCIDENCE IN CUCUMBER (2025)

Treatment	Wilt (%) 25 DAS	Wilt (%) 50 DAS	Wilt (%) 75 DAS	Yield (t/ha)	B:C ratio
Module 1	0.00	0.00	8.00	8.52	2.54
Module 2	0.00	0.00	7.72	9.00	2.92
Module 3	0.00	0.00	11.40	8.20	2.70
Module 4 (Control)	12.50	21.80	46.20	6.13	2.10
SED	0.06	0.23	0.49	0.15	0.03
CD (0.05)	0.13	0.48	1.05	0.32	0.06
CV	2.41	2.30	2.53	1.19	1.38

3.2.2 Second-year field trial (2026)

The second-year trial showed a trend similar to the first year (Table 5). Module 2 recorded the minimum disease incidence (15.40%) and the highest yield (9.32 t/ha), and was as effective as the chemical treatment (Module 3), which recorded 15.72% wilt incidence and a yield of 8.30 t/ha. In the control, disease incidence was highest (48.20% at 75 DAS) and yield lowest (5.62 t/ha).

TABLE 5
EFFECT OF DIFFERENT IDM MODULES ON WILT INCIDENCE IN CUCUMBER (2026)

Treatment	Wilt (%) 25 DAS	Wilt (%) 50 DAS	Wilt (%) 75 DAS	Yield (t/ha)	B:C ratio
Module 1	0.00	0.00	17.22	8.18	2.74
Module 2	0.00	0.00	15.40	9.32	2.95
Module 3	0.00	0.00	15.72	8.30	2.85
Module 4 (Control)	10.00	25.10	48.20	5.62	2.29
SED	0.08	0.18	0.63	0.12	0.05
CD (0.05)	0.17	0.39	1.35	0.27	0.10
CV	3.80	2.71	2.79	1.94	2.04

3.2.3 Pooled analysis

Pooled analysis of the 2025 and 2026 trials showed that Module 2 recorded the minimum disease incidence (11.60%) and the highest yield (9.20 t/ha), compared with the control, which recorded the maximum disease incidence (47.30% at 75 DAS) and the lowest yield (5.90 t/ha) (Table 6).

TABLE 6
POOLED ANALYSIS OF THE EFFECT OF DIFFERENT IDM MODULES ON WILT INCIDENCE IN CUCUMBER (2025 AND 2026)

Treatment	Wilt (%) 25 DAS	Wilt (%) 50 DAS	Wilt (%) 75 DAS	Yield (t/ha)	B:C ratio
Module 1	0.00	0.00	12.60	8.40	2.60
Module 2	0.00	0.00	11.60	9.20	2.90
Module 3	0.00	0.00	11.81	8.30	2.80
Module 4 (Control)	11.30	23.45	47.30	5.90	2.195
SED	0.07	0.205	0.56	0.39	0.04
CD (0.05)	0.15	0.435	1.20	0.835	0.08
CV	3.105	2.505	2.66	1.99	1.71

IV. DISCUSSION

The field results show that Module 2 gave the most consistent wilt suppression, highest yield, and best benefit-cost ratio across two seasons, which fits the broader pattern that combining compatible biological agents outperforms single-tactic management in cucumber wilt systems. Dual or multi-agent biocontrol combinations repeatedly produced stronger disease suppression than single strains, including *Bacillus*–fungus combinations, *Bacillus–Trichoderma* mixtures, and larger consortia under protected or greenhouse conditions (Luo *et al*., 2026; Wang *et al*., 2021; Singh & Balodi, 2021; Hussein, 2016).

This advantage is biologically plausible because cucumber wilt is a persistent soil-borne vascular disease with long-lived chlamydospores, wide field prevalence, and strong dependence on soil and rhizosphere conditions, so no single intervention is usually sufficient (Haridasan & Sajeena, 2025; Din *et al*., 2020).

Module 2 likely performed best because it integrated seed treatment, soil application, and root-zone drenching, thereby protecting the crop at multiple infection stages. Similar studies show that *Bacillus* and *Trichoderma* combinations suppress *Fusarium* wilt more effectively when applied through root irrigation, soil drench, or seed-plus-soil delivery rather than as a single exposure (Luo *et al*., 2026; Singh & Balodi, 2021; Brar *et al*., 2025).

The superiority of the biological module over the untreated control also agrees with reports that *Bacillus*-based and *Trichoderma*-based treatments reduce cucumber wilt while improving plant growth. Field or pot studies with *Bacillus subtilis*, *Bacillus velezensis*, *Streptomyces rochei*, and *Trichoderma* spp. all reported meaningful reductions in disease incidence or disease index together with increases in biomass or vigor (Yang *et al*., 2024; Ta *et al*., 2024; Zhu *et al*., 2024; Waris *et al*., 2025).

A likely reason is that these bioagents act through multiple complementary mechanisms. Reported mechanisms include antimicrobial activity, nutrient and niche competition, root colonization, siderophore or IAA production, degradation of disease-promoting phenolics, and enrichment of beneficial rhizosphere taxa that suppress *Fusarium* proliferation (Wang *et al*., 2021; Ta *et al*., 2024; Luo *et al*., 2026).

Another relevant explanation is induction of host defense and improvement of the soil biochemical environment. *Bacillus*-, *Streptomyces*-, and silicon-based studies showed higher antioxidant or defense-related enzyme activity and lower oxidative damage in treated cucumber plants, indicating that wilt reduction is not only due to direct antagonism but also to stronger host resistance (Yang *et al*., 2024; Zhu *et al*., 2024; Ta *et al*., 2024; Sun *et al*., 2022).

The inclusion of clove oil in Module 2 may also have contributed to performance because broader IDM literature supports adding eco-compatible inputs to biological modules. Botanical or low-risk inputs such as neem formulations, salicylic acid, silicon, L-arabinose, and integrated amendment systems have reduced disease pressure or enhanced resistance while lowering dependence on conventional chemicals (Dey *et al*., 2025; Yu *et al*., 2024; Sun *et al*., 2022; Hussein, 2016; Tang *et al*., 2020).

Although Module 3 also reduced wilt effectively, the broader literature explains why sole chemical dependence is less attractive as a long-term strategy. Chemical and fumigant approaches can be limited by residue concerns, environmental risk, cost, and

resistance development, whereas integrated systems are designed to keep disease below economic thresholds with lower ecological burden (Haridasan & Sajeena, 2025; Yu *et al*., 2024; Mahmood *et al*., 2023; Sarkar *et al*., 2025).

The survey data in the Coimbatore region, showing marked location-to-location variation in wilt incidence, are also consistent with earlier prevalence studies. Cucumber wilt incidence has been reported from roughly 10% to 60% in field surveys and can exceed 50% under severe production conditions, especially in continuously cropped systems (Din *et al*., 2020; Zhu *et al*., 2024; Wang *et al*., 2021; Sun *et al*., 2022).

V. CONCLUSION

The study indicates that IDM Module 2 was the most effective option for managing cucumber wilt under the tested field conditions, as it minimized wilt incidence and maximized yield and economic return across both years.

Taken together with the wider literature, the results support a bio-intensive IDM strategy built around *Bacillus*- and *Trichoderma*-based consortia, supported by compatible cultural or botanical inputs, as a more sustainable alternative to sole chemical management. Module 2, comprising microbial consortia-based seed, soil, and drench applications, can be recommended as an effective and eco-friendlier IDM module for wilt management in cucumber under Coimbatore conditions.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

[1] Brar, G., Singh, N., Buttar, D. S., & Choudhary, A. K. (2025). Management of cucumber wilt using the potential native biocontrol agents. *The Indian Journal of Agricultural Sciences*. https://doi.org/10.56093/ijas.v95i9.150802

[2] Daunde, A. T., Baghele, R., & Khandare, V. (2020). Management of prevalent diseases of cucumber (*Cucumis sativus*) through integrated approach. *International Journal of Current Microbiology and Applied Sciences*, *9*, 3022-3028. https://doi.org/10.20546/ijcmas.2020.907.355

[3] Dey, P., Rajkumari, P., Deka, S. D., & Mishra, R. (2025). Integrated approaches to combat cucurbit mosaic disease in *Cucumis sativus*: Insights from Assam, India. *Journal of Advances in Biology & Biotechnology*. https://doi.org/10.9734/jabb/2025/v28i11919

[4] Din, H. M., Rashed, O., & Ahmad, K. (2020). Prevalence of Fusarium wilt disease of cucumber (*Cucumis sativus* Linn) in Peninsular Malaysia caused by *Fusarium oxysporum* and *F. solani*. *Tropical Life Sciences Research*, *31*, 29-45. https://doi.org/10.21315/tlsr2020.31.3.3

[5] Haridasan, N., & Sajeena, A. (2025). Unravelling the intricacies in the management of Fusarium wilts of vegetable crops. *International Journal of Agricultural Sciences*. https://doi.org/10.15740/has/ijas/21.1/194-211

[6] Hussein, S. (2016). Molecular identification and integrated management of the *Fusarium* f. sp. *cucumerinum* the causal agent of Fusarium wilt disease of *Cucumis sativus* L. in Iraq. *Journal of Experimental Biology and Agricultural Sciences*, *4*, 389-397. https://doi.org/10.18006/2016.4(4).389.397

[7] Luo, X., Ouyang, J., Li, J., Yu, H., Guo, S., Zeng, X.-Z., Zhou, Z., Shangguan, Y., He, M., Ouyang, Y., Chen, K., & Qin, Y. (2026). Combining *Bacillus* and *Trichoderma* in bio-organic fertilizers with reduced chemical fertilizer: An effective strategy against cucumber Fusarium wilt. *Plants*, *15*. https://doi.org/10.3390/plants15050782

[8] Mahmood, U., Inam-Ul-Haq, M., Irshad, G., & Hayat, R. (2023). Integration of rhizobacterial isolates and Airone chemical for effective management of bacterial wilt in cucumber (*Cucumis sativus*). *International Journal of Phytopathology*. https://doi.org/10.33687/phytopath.012.03.4986

[9] Mouhsan, Z. M. (2026). Integrated management of cucumber damping-off disease caused by the fungus *Rhizoctonia solani* using some environmentally friendly agents. *Madras Agricultural Journal*. https://doi.org/10.29321/maj.10.261321

[10] Sarkar, S., Mohanty, A., Dash, S., Das, S., & Behera, A. (2025). Integrated management strategies for prevalent diseases of cucumber (*Cucumis sativus* L.) under Odisha condition. *Journal of Advances in Biology & Biotechnology*. https://doi.org/10.9734/jabb/2025/v28i62489

[11] Sharma, D., & Shukla, A. (2021). Fusarium wilt of cucumber—A review. *International Journal of Economic Plants*. https://doi.org/10.23910/2/2021.0423

[12] Singh, S., & Balodi, R. (2021). Bio-management of soil borne pathogens infesting cucumber (*Cucumis sativus* L.) under protected cultivation system. *Biological Control*. https://doi.org/10.1016/j.biocontrol.2021.104569

[13] Sun, S., Yang, Z.-L., Song, Z., Wang, N.-N., Guo, N., Niu, J.-S., Liu, A.-R., Bai, B., Ahammed, G., & Chen, S.-C. (2022). Silicon enhances plant resistance to Fusarium wilt by promoting antioxidant potential and photosynthetic capacity in cucumber (*Cucumis sativus* L.). *Frontiers in Plant Science*, *13*. https://doi.org/10.3389/fpls.2022.1011859

[14] Ta, Y.-Q., Fu, S., Liu, H., Zhang, C.-Y., He, M., Yu, H., Ren, Y.-H., Han, Y., Hu, W., Yan, Z., & Wang, Y.-H. (2024). Evaluation of *Bacillus velezensis* F9 for cucumber growth promotion and suppression of Fusarium wilt disease. *Microorganisms*, *12*. https://doi.org/10.3390/microorganisms12091882

[15] Tang, L., Hamid, Y., Chen, Z., Lin, Q., Shohag, M., He, Z.-L., & Yang, X. (2020). A phytoremediation coupled with agro-production mode suppresses Fusarium wilt disease and alleviates cadmium phytotoxicity of cucumber (*Cucumis sativus* L.) in continuous cropping greenhouse soil. *Chemosphere*, 128634. https://doi.org/10.1016/j.chemosphere.2020.128634

[16] Wang, H.-W., Cai, X., Xu, M., & Tian, F. (2021). Enhanced biocontrol of cucumber Fusarium wilt by combined application of new antagonistic bacteria *Bacillus amyloliquefaciens* B2 and phenolic acid-degrading fungus *Pleurotus ostreatus* P5. *Frontiers in Microbiology*, *12*. https://doi.org/10.3389/fmicb.2021.700142

[17] Waris, M., Baloch, A., Abro, M. A., B., Dad, S., Din, R. U., & Murad, J. (2025). Biological control of Fusarium wilt of cucumber under in-vitro condition and in high tunnels. *Pakistan Journal of Phytopathology*. https://doi.org/10.33866/phytopathol.037.02.1305

[18] Yang, W., Wang, L., Li, X., Yan, H.-X., Zhong, B., Du, X., Guo, Q., He, T., & Luo, Y.-M. (2024). Biological control potential of *Bacillus subtilis* isolate 1JN2 against Fusarium wilt on cucumber. *Horticulturae*. https://doi.org/10.3390/horticulturae10080843

[19] Yu, M., Yuliana, R., Tumewu, S. A., Bao, W.-X., Suga, H., & Shimizu, M. (2024). Efficacy of L-arabinose in managing cucumber Fusarium wilt and the underlying mechanism of action. *Pest Management Science*, *81*, 1239-1250. https://doi.org/10.1002/ps.8523

[20] Zhu, C., Li, X., Gao, Y., Yang, X., Gao, Y.-L., & Li, K. (2024). Potential of *Streptomyces rochei* G-6 for biocontrol of cucumber wilt disease and growth enhancement. *Journal of Fungi*, *10*. https://doi.org/10.3390/jof10120885.