Can you manage downy mildew in hydroponic basil with organic foliar sprays?

Basil downy mildew, caused by the obligate oomycete *Peronospora belbahrii*, has become one of the most serious diseases affecting hydroponic and greenhouse basil production globally. The pathogen, first documented in Europe in 2001 and later detected in the United States in 2007, requires high relative humidity (at least 85%) or wet leaves to infect plants (1). Temperature preferences favor moderate conditions around 20°C rather than higher temperatures, which explains why the disease thrives in controlled environment systems where leaf wetness and humidity are difficult to manage (1).

Downy mildew in basil shows characteristic black marks on the underside of leaves

Understanding the infection process is critical for designing effective spray programs. Under conditions of continuous free moisture, sporangia germinate within 3 to 5 days by producing germ tubes that penetrate basil leaves directly through the epidermis, typically without entering through stomata (2).

Seven days after initial infection, sporangiophores bearing new sporangia emerge through stomata on both the upper and lower leaf surfaces, creating secondary inoculum that spreads rapidly throughout greenhouse facilities (2). This relatively short cycle from infection to sporulation means that preventive measures must start before visible symptoms appear.

Multiple field trials evaluating organic fungicides have delivered sobering results for growers seeking alternatives to conventional chemistry. A comprehensive study testing products approved for organic production, including copper octanoate, hydrogen dioxide, sesame oil, neem oil, thyme oil, citric acid, *Bacillus* species, and *Streptomyces lydicus*, found that none were effective at controlling downy mildew when applied to susceptible basil cultivars (3). Applications were made weekly starting before symptom development, and efficacy was assessed based on incidence of symptomatic leaves rather than severity, reflecting the zero tolerance for disease on fresh market herbs (3). A summary of the tested fungicides and their effectiveness is shown on the following table.

Product (Active Ingredient)	Mode of Action	Effectiveness
Cueva (Copper octanoate)	Contact fungicide, disrupts enzyme function	Ineffective
OxiDate (Hydrogen dioxide)	Oxidizing agent, contact action	Ineffective
Organocide (Sesame oil)	Physical barrier, suffocation	Ineffective
Trilogy (Neem oil)	Physical barrier, azadirachtin content	Ineffective
Forticept EP #1 (Thyme oil)	Essential oil, contact action	Ineffective

Product (Active Ingredient)	Mode of Action	Effectiveness
Procidic (Citric acid)	pH modulation, contact action	Ineffective
Actinovate (*Streptomyces lydicus*)	Biocontrol, competitive colonization	Ineffective
Companion (*Bacillus subtilis*)	Biocontrol, induced resistance	Ineffective
Double Nickel (*B. amyloliquefaciens*)	Biocontrol, antibiosis	Ineffective
Regalia (*Reynoutria sachalinensis*)	Plant defense activator	Ineffective

The limited efficacy of organic fungicides appears related to the aggressive nature of the pathogen and the difficulty of achieving thorough foliar coverage in dense basil canopies. Even when combined with resistance inducers or natural products, organic treatments failed to provide commercially acceptable levels of disease suppression (5).

Environmental management offers more promise than chemical sprays alone. Light suppresses sporulation of *P. belbahrii*, with continuous light or supplemental lighting during nighttime hours substantially reducing spore production (6). Growers can exploit this by maintaining photoperiods longer than 13 hours or by using low-intensity supplemental lighting during dark periods. Reducing leaf wetness duration is equally important because the pathogen requires at least 24 hours of continuous moisture for infection and dense sporulation (7). In hydroponic systems, switching from overhead misting to sub-canopy irrigation and increasing air movement with horizontal airflow fans can dramatically reduce infection pressure (8).

Temperature manipulation provides another non-chemical tool. Passive heat treatment using transparent plastic covers to raise greenhouse temperatures during sunny periods suppressed downy mildew development without damaging basil plants (9). Temperatures above 30°C inhibit sporangiophore formation and sporangial germination, though plants must be acclimated gradually to avoid heat stress. This approach works best in greenhouse operations with sufficient ventilation control and may be less practical in open hydroponic facilities.

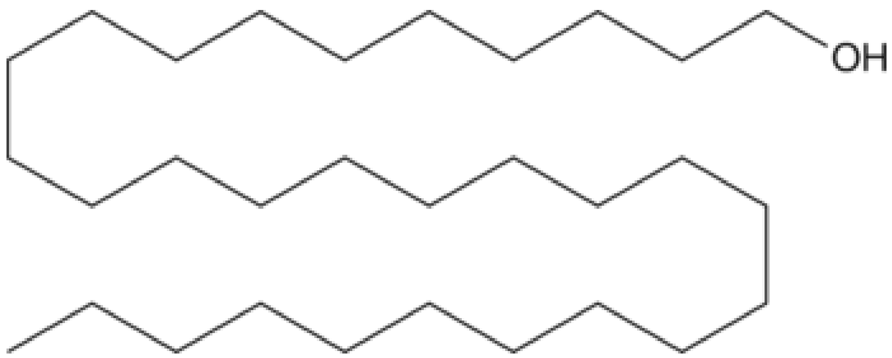
Varietal resistance remains the most effective long-term strategy for hydroponic basil growers. Breeding efforts have identified resistance sources in wild basil species *Ocimum americanum*, and these traits have been successfully transferred into sweet basil backgrounds (10). Commercial varieties with improved resistance are now available, though complete immunity has not been achieved. Growers should prioritize these resistant cultivars and combine them with environmental controls rather than relying on organic fungicide sprays.

Cropping system modifications can reduce disease pressure in organic systems. Research on open field organic production found that sparse sowing density combined with resistant varieties provided better control than chemical treatments alone (11). In hydroponics, maintaining wider plant spacing, particularly in NFT or DWC systems where humidity tends to be higher, allows better air circulation and faster leaf drying after irrigation events.

The reality for hydroponic basil producers is that organic foliar sprays, when used alone, will not provide adequate downy mildew control on susceptible varieties. The pathogen's rapid lifecycle, preference for humid greenhouse conditions, and resistance to contact fungicides makes chemical intervention largely ineffective without supporting measures. Successful organic management requires integrating resistant varieties, environmental manipulation (particularly light, humidity, and leaf wetness control), appropriate plant spacing, and vigilant monitoring for early disease detection. Growers who continue relying primarily on organic sprays should expect continued losses, while those who adopt integrated approaches combining genetics and environment will achieve better results.

Triacontanol Foliar Sprays in Soilless Culture: Formulation and Application

Triacontanol is a naturally occurring long-chain fatty alcohol found in plant cuticle waxes that can act as a growth regulator at very low concentrations. Below I focus on peer-reviewed evidence for triacontanol in hydroponic and soilless systems, with attention to preparation methods, yield effects, and quality outcomes in tomatoes, cucumbers, strawberries, and lettuce.



Above you can see a representative model of triacontanol. Chemically triacontanol is a long-chain fatty alcohol, very hard to dissolve in water and apply effectively to plants.

Evidence for Yield and Quality Effects

Hydroponic lettuce. Foliar application of triacontanol at

10^{-7} M (approximately 0.043 mg/L) to 4-day-old hydroponically grown lettuce seedlings increased leaf fresh weight by 13-20% and root fresh weight by 13-24% within 6 days. (1) When applied at both 4 and 8 days after seeding, leaf area and mean relative growth rate increased by 12-37%. There was no additional benefit from repeating applications beyond two sprays in this short-cycle crop.

Tomato in hydroponic systems. Weekly foliar applications of 70 μM triacontanol (approximately 21 mg/L) on tomatoes grown in hydroponic drip systems significantly increased flower number by 37-50% and total fruit number by 22-57%, resulting in a 28% higher total yield at harvest. (2) Individual fruit weight decreased by 16%, but the net effect on total productivity remained positive. The treatment advanced blooming without affecting plant height or internode number, demonstrating a specific effect on reproductive development.

Cucumber under soilless conditions. Foliar application of triacontanol at 0.8 mg/L on cucumber genotypes under salt stress improved photosynthesis, stomatal conductance, and water use efficiency. (3) The treatment enhanced antioxidant enzyme activities and maintained better membrane stability. Yield traits, including fruit number and average fruit weight, improved in response to triacontanol application. Salt-tolerant genotypes (Green long and Marketmore) showed greater responsiveness than sensitive genotypes.

Strawberry. Triacontanol has shown promise in improving drought tolerance in strawberry plants by enhancing growth, productivity, and physiological performance, though most work has been conducted in soil rather than true soilless systems. (4)

Formulation: Creating a

Concentrated Stock Solution

Triacontanol has extremely low water solubility (less than 1 mg/L at room temperature), which makes proper formulation critical. The most reliable approach combines an organic solvent with a surfactant to create a stable concentrate that can be diluted into spray solutions.

Stock Solution Protocol

Materials needed:

- Triacontanol powder (90%+ purity)
- Ethanol (95% or higher)
- Tween-20 or Tween-80 (polysorbate surfactant)
- Distilled or deionized water
- Glass or high-density polyethylene containers

Preparation of 1000 mg/L (1000 ppm) stock:

1. Weigh 1000 mg of triacontanol powder using an analytical balance.
2. Dissolve the triacontanol in 100 mL of 95% ethanol in a glass beaker. Warm gently (35-40°C) while stirring with a magnetic stirrer for 15-20 minutes to ensure complete dissolution. Do not exceed 50°C.
3. Add 5 mL of Tween-20 to the ethanol solution and mix thoroughly for 5 minutes. This surfactant concentration (0.5% v/v in final volume) ensures proper emulsification and leaf surface wetting.
4. Transfer the ethanol-triacontanol-surfactant mixture to a 1000 mL volumetric flask.
5. Bring to final volume with distilled water while mixing continuously. The solution will appear slightly cloudy due to micelle formation, which is expected and desirable.

6. Store the stock solution in an amber glass bottle at room temperature. The stock is stable for 3-4 months when protected from light and heat.

Alternative solvent systems: Some studies have successfully used isopropanol or acetone as solvents. (5) However, ethanol provides the best combination of triacontanol solubility, plant safety, and ease of handling for growers.

Working Solution Preparation

Dilute the 1000 mg/L stock to achieve target concentrations based on crop and growth stage:

Lettuce: Dilute 1:10,000 to 1:20,000 for final concentrations of 0.05-0.1 mg/L. For a 1-liter spray bottle, add 0.05-0.1 mL of stock solution.

Tomato: Dilute 1:50 for final concentration of 20 mg/L. For a 1-liter spray bottle, add 20 mL of stock solution.

Cucumber: Dilute 1:1250 for final concentration of 0.8 mg/L. For a 1-liter spray bottle, add 0.8 mL of stock solution.

Add an additional 0.1% v/v Tween-20 (1 mL per liter) to the final spray solution to ensure maximum leaf coverage and absorption. This additional surfactant enhances uptake without phytotoxicity when concentrations remain below 0.2%. (3)

Application Timing and Frequency

Seedling stage: Apply once at 4-8 days after emergence for leafy greens in short-cycle production. A single early application is often sufficient for lettuce. (1)

Vegetative and reproductive stages: For fruiting crops like tomato and cucumber, apply weekly starting 4 weeks after transplant and continuing through flowering and early fruit set. Three to five applications total are typically used. (2) (3)

Application method: Apply using a hand sprayer or backpack sprayer with a cone nozzle, ensuring complete leaf coverage including undersides. Apply in early morning or late afternoon to maximize absorption and minimize evaporation. Spray until runoff just begins.

Reported Effects Across Crops

Crop	Concentration	Application schedule	Yield effect	Quality effect	Reference
Lettuce (hydroponic)	0.043 mg/L	Once at day 4, optional repeat at day 8	Fresh weight +13-20%, leaf area +12-37%	Not assessed	(1)
Tomato (hydroponic drip)	21 mg/L	Weekly from week 4 through fruit set	Total yield +28%, fruit number +22-57%	Minimal changes in soluble solids, lycopene, vitamin C	(2)
Cucumber (soilless, salt stress)	0.8 mg/L	Three sprays: 72h after stress, at flowering, at fruit maturity	Improved fruit number and weight under stress	Maintained lower electrolyte leakage, higher chlorophyll	(3)

Mechanisms and Considerations

Triacontanol acts through a secondary messenger system involving 9-L(+)-adenosine, which triggers rapid ion influx (Ca^{2+}, K^{+}, Mg^{2+}) and modulates gene expression related to photosynthesis, hormone balance, and stress responses. (2) The compound enhances photosynthetic rate, stomatal conductance, and nutrient uptake at very low doses.

Concentration matters. Response curves show classic hormesis: stimulation at low concentrations, no effect or inhibition at higher doses. The optimal range is crop-specific but generally falls between 0.05-20 mg/L for foliar applications. Lettuce seems to respond to much lower concentrations than tomatoes.

Environmental and genetic factors influence response magnitude. Tolerant cucumber genotypes showed larger yield improvements than sensitive ones. (3) Season, light intensity, and nutrient status affect outcomes.

Triacontanol enhances stress tolerance, particularly to salinity and drought, by improving antioxidant enzyme activity, maintaining membrane integrity, and regulating osmotic adjustment. (3) (4) This makes it especially valuable in recirculating hydroponic systems where EC can drift upward.

Practical Guidelines

- Test on a small number of plants before scaling to full production.
- Keep application rates within published ranges. More is not better with triacontanol.
- Maintain consistent spray timing rather than irregular high-dose applications.
- Store stock solutions away from light and heat to preserve activity.
- Use analytical-grade triacontanol from reputable suppliers (minimum 90% purity).
- Combine with sound nutritional management; triacontanol is not a substitute for balanced feeding. Triacontanol is not a replacement for proper nutrition, irrigation, environmental conditions or media management.

Properly formulated and applied, triacontanol provides measurable improvements in productivity and stress tolerance across major soilless crops. The citations above offer detailed protocols and results for those wishing to implement this growth regulator in commercial or research settings.

Calcium silicate (wollastonite) in soilless crops

Silicon in media is not a magic switch. In soilless systems it can help, it can do nothing, and at the wrong rate or pH it can hurt. Calcium silicate sources such as wollastonite release plant-available Si into inert substrates and typically raise pH, which is useful in peat but potentially more risky in coir or already alkaline systems. A recent substrate study quantified this clearly: wollastonite steadily released Si for months and increased media pH about 0.5 to 1 unit depending on substrate composition (1). With that in mind, here is the evidence for tomatoes and cucumbers grown without soil, focusing only on media or root-zone applications.

Vansil CS-1, one of the most common forms of calcium silicate (wollastonite) used as an amendment in soilless crops.

Tomatoes

Two independent Brazilian groups that amended substrate with calcium silicate found quality benefits but also rate-sensitivity. In a factorial test across Si sources and doses, calcium silicate treatments improved postharvest durability and maintained physicochemical quality of fruits; the effect size depended on the source and the dose used (2). A protected-environment pot study that mixed calcium silicate into the substrate before transplanting reported reductions in gas exchange and chlorophyll at midcycle at higher rates, a warning that more is not always better (3). Earlier yield work that compared sources also detected response to silicon fertilization in tomatoes, but the magnitude varied with rate and material (4).

Cucumbers

When wollastonite was incorporated into the soilless substrate, 3 g L^{-1} increased yield by ~25% under moderate moisture restriction, with no penalty to soluble solids or fruit size. Lower doses or excessive irrigation did less (5). A separate work that applied a calcium-silicate solution into the substrate showed small gains in biomass under specific moisture regimes and no change in soluble solids, again pointing to context and dose as the deciding factors (6).

Practical takeaways for media use

1. Treat calcium silicate like a weak liming Si source. Expect a pH rise. In peat this can be helpful, in coir or high-alkalinity waters it can push you out of range (1).
2. Dose conservatively, then verify with tissue Si or leachate pH before scaling. Tomatoes show rate-sensitive physiology (3).
3. Target crops and situations with the strongest evidence. Cucumbers under moderate moisture restriction and strawberries in organic substrates show the clearest yield and quality benefits (5), (7).

Summary table – media or root-zone Si only

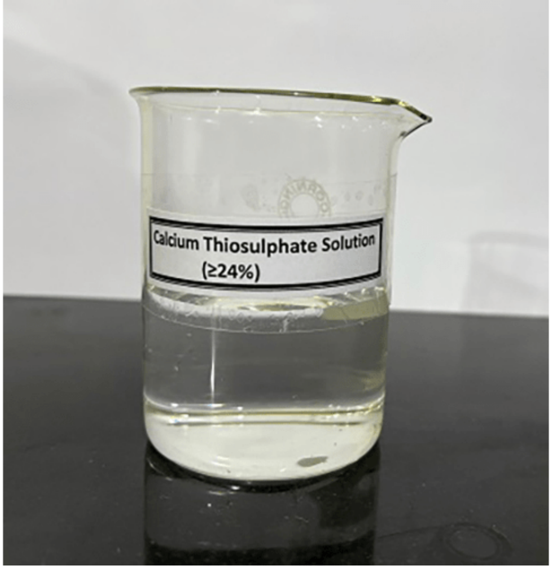
Crop	Medium and Si source	Application rate	Positive effects on yield or quality	Reported negatives	Ref
Tomato	Substrate mix, calcium silicate among Si sources	Field-equivalent 0 to 800 kg SiO_2 ha^{-1} mixed pre-plant	Improved postharvest durability and maintained physicochemical quality vs control; effect depended on dose and source	None specified at optimal rates	(2)
Tomato	Substrate, calcium silicate mixed before transplant	0, 150, 300, 450, 600 kg ha^{-1}	–	Reduced gas exchange and chlorophyll at midcycle at higher rates, indicating potential performance penalty	(3)
Tomato	Substrate, silicon sources including calcium silicate	Multiple rates	Yield responded to Si fertilization depending on source and rate	–	(4)
Cucumber	Soilless substrate, wollastonite	3 g L^{-1} of substrate under 75-85% container capacity	+24.9% yield vs untreated; fruit size and soluble solids unchanged	None noted at that rate	(5)
Cucumber	Substrate drench, calcium silicate solution	50-100 mg L^{-1} SiO_2 applied to substrate	Biomass gains under specific moisture regimes; quality unchanged	No quality gain at tested doses; response moisture-dependent	(6)
Any	Peat or coir mixes, wollastonite	~1 g L^{-1} media typical in study	Steady Si release over months supports long crops	Raises media pH by about 0.5-1 unit depending on substrate	(1)

Bottom line

Use calcium silicate where the crop and context justify it, not by default. For cucumbers and strawberries the upside on yield and quality is most consistent when Si is in the root zone. For tomatoes, treat calcium silicate as a quality tool with a narrow window and verify plant response; higher rates can backfire physiologically. If you want to try calcium silicate, mix wollastonite with your media at a rate of 3g L^{-1}, then test the effect on pH and Si in tissue.

Calcium Thiosulfate as a Nitrate-Free Calcium Source in Soilless Culture

Growers often supply calcium (Ca) with calcium nitrate, but that introduces unwanted nitrogen (N). To achieve a 0% N finish in a hydroponic or soilless system (for instance to reduce residual nitrates or alter plant metabolism), an alternative Ca source is required. One option is calcium thiosulfate (CaS_2O_3), a clear, water-soluble liquid containing about **6% Ca** and **10% thiosulfate sulfur**. Tessenderlo Kerley's CaTSR product is labeled 0-0-0-10S-6Ca (no N), and can replace $Ca(NO_3)_2$ or $CaCl_2$ in late-stage fertigation (zero-nitrogen) regimes.



Calcium thiosulfate is very soluble and can be used to prepare highly concentrated solutions

Calcium fertilizer	Ca (%)	N (%)	Other ions / comments
Calcium nitrate ($Ca(NO_3)_2$)	~19	~16	NO_3^- (adds N)
Calcium chloride ($CaCl_2 \cdot 2H_2O$)	~27	0	add a lot of Cl^- (1.7ppm per ppm of Ca); very soluble
Calcium sulfate ($CaSO_4 \cdot 2H_2O$)	~23	0	SO_4^{2-}; low solubility (gypsum), cannot be used to make stocks
Calcium thiosulfate (liquid)	~6	0	$S_2O_3^{2-}$; high solubility, ~10% S

Evidence and Discussion

Because research specifically on calcium thiosulfate (CaTS) is scarce, I evaluated what I *could* verify.

- A peer-reviewed article “Effects of Thiosulfate as a Sulfur Source on Plant Growth, Metabolites Accumulation and Gene Expression in Arabidopsis and Rice" studied whether plants could use thiosulfate (instead of sulfate) in hydroponic medium. The study found that both Arabidopsis (dicot) and rice (monocot) take up thiosulfate into roots, and that at modest sulfur levels (≈300 µM) rice shows similar biomass whether S is supplied as thiosulfate or sulfate. The Arabidopsis biomass was lower when thiosulfate was used above certain concentration thresholds. This shows thiosulfate is bioavailable, though with caveats depending on species, concentration and potential toxicity or metabolic cost in dicots (1).

- Another verified study "Soil Calcium Status Unrelated to Tipburn of Romaine" (Hartz et al., 2007) compared calcium nitrate, calcium thiosulfate, and calcium chloride injections via drip in field soil on romaine lettuce. They applied 17-28 kg Ca/ha in the last 1-3 weeks before harvest and found **no significant improvement** in leaf Ca concentration of inner leaves, nor reduction of tipburn severity, regardless of Ca source (2).
- Also, "Calcium Fertigation Ineffective at Increasing Fruit Yield and Quality of Muskmelon and Honeydew Melons in California" (Johnstone et al., 2008) compared calcium from calcium nitrate, calcium thiosulfate, and calcium chloride under drip irrigation in melon. Applications of typical industry rates of Ca via CTS or CN or Cl did **not** improve fruit yield, quality, or tissue Ca concentration compared to no-Ca-fertigation control (3).

So far **no** peer-reviewed study was found that examines Ca thiosulfate in *pure hydroponic* or soilless culture to replace calcium nitrate when aiming for zero N finish (apart from its use as a sulfur source). The field soil/field drip results tend to show minimal effect of late calcium injection for inner leaves or fruit quality under the tested conditions.

With that said, studies have not revealed any negative effects from using calcium thiosulfate. My experience has shown no problems when using Ca thiosulfate as a zero-nitrogen Ca source at reasonable concentrations.

Implications

Given limited evidence, growers should be skeptical about expecting large gains in tissue calcium or disorder reduction simply by switching sources late in growth, especially under field or substrate conditions. However, using CaTSR is valid if your goal is to maintain calcium without adding nitrogen. Because it is soluble and delivers Ca in a bioavailable way (and provides thiosulfate that plants can absorb), it’s a workable tool in finish regimes where N must be zero or near zero.

The tradeoffs include:

- Possible metabolic cost in some species under certain S forms or concentrations
- If the calcium demand is high, source competition or diffusion limitations may still constrain uptake
- The very late supply may not change internal partitioning or yield, as many trials showed

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Preparing a Stock Solution and Dosing

Here is a practical plan to use CaTSR to reach **120 ppm Ca** in the final crop solution, with a **1:100 injection ratio**, without introducing nitrogen:

1. **Determine Ca content.** CaTSR is labeled as ~6% Ca by weight (≈60 g Ca per liter if density ~1 kg/L). Confirm with product label or lab test.
2. **Stock concentration target.** To get 120 ppm in the working solution via 1:100 injection, the stock needs to be ~100× that: **12000 ppm Ca** in stock.
3. **Stock solution dilution.** Since CaTSR has ~60000 ppm Ca when pure (100%), you need ~20% of that pure product in stock to get 12000 ppm. This means uou should add ~200mL/L (~750mL/gal) of stock with the rest being distilled or RO water. This should replace your normal Ca nitrate stock.
4. **Injection.** Use an injector that can do 1% injection (38mL/gal). That gives ~120 ppm Ca.
5. **Adjustments.** If the product is more dilute or denser, revise proportionally; check electrical conductivity (EC) and pH when adding CaTSR as it may shift pH or interact with other ions.

Summary

Using calcium thiosulfate (e.g. CaTSR 0-0-0-10S-6Ca) allows growers to maintain calcium levels while eliminating added nitrogen. The dilution above (~20% product in stock, injected 1:100) yields ~120 ppm Ca. Existing studies show thiosulfate is absorbed and usable (1), but field trials using CaTS late in growth often do **not** show improvements in tissue Ca, yield, or quality when compared to controls using other Ca sources or none (2), (3). Growers should expect moderate effects at best in substrate or field systems, unless other limiting factors are addressed.

A low cost DIY oil IPM for your crops

An emulsified vegetable oil spray can smother mites and soft-bodied insects and can suppress powdery mildew if you actually coat the target. Soybean oil has the strongest evidence. Corn oil works too, and blending the two offers some advantages. In the following article I tell you how to prepare such a spray as well as some of the scientific evidence showing how it works.

Corn oil, one of the main components of this IPM spray

Why combine soybean and corn oil?

- **Fatty acid profiles differ.** Soybean oil is richer in unsaturated fatty acids (linoleic, linolenic), while corn oil contains more oleic and palmitic. That mix can change the viscosity and spreading behavior on leaves.
- **Broader efficacy.** Soybean oil has strong data against

powdery mildew, mites, and whiteflies (1) (2) (3). Corn oil has been validated in cucumber mildew trials (5). Using both hedges against variability between pests and crops.

- **Physical properties.** Mixed oils can emulsify more easily and form finer droplets than a single oil, which may improve coverage and reduce visible residues.

Why use both Tween 20 and Tween 80?

- **Hydrophilic balance.** Tween 20 (polyoxyethylene sorbitan monolaurate) is more hydrophilic, while Tween 80 (polyoxyethylene sorbitan monooleate) is more lipophilic. Together, they stabilize emulsions of mixed triglyceride oils better than either one alone.
- **Reduced creaming/separation.** A dual-Tween system forms smaller, more stable droplets that resist breaking apart. This means the concentrate stays uniform longer and the spray deposits more evenly on foliage (4).

Step 1. Prepare the concentrate

Mix in a clean container:

- **Soybean oil:** 200 mL per liter (~760 mL per US gallon)
- **Corn oil:** 200 mL per liter (~760 mL per US gallon)
- **Tween 20:** 10 mL per liter (~38 mL per gallon)
- **Tween 80:** 10 mL per liter (~38 mL per gallon)
- Fill with clean water to reach 1 L (or 1 gal).

Mix for at least 30 minutes, ensure it is uniform. Always mix well before use. This is the concentrate: **20% soybean oil, 20% corn oil, 1% Tween 20, 1% Tween 80**.

Step 2. Dilute for spraying

For foliar application:

- **Dilution rate:** Add ~20mL of concentrate per liter of water (~75 mL per US gallon of water). If pests are present you can increase the rate up to 32mL/L (~120mL/gal).
- **Note on coverage:** Coverage is critical for this spray to work as it only kills insects on contact or prevents PM by building an oil film on the leaf that prevents spore germination. Without full coverage effectiveness will drop.

This produces a **0.8% oil spray** with **0.02% Tween 20 and 0.02% Tween 80** in the final spray solution. Mix well before use.

Shelf life considerations

- **Concentrate:** A freshly prepared concentrate can stay stable for several weeks if kept sealed, cool, and out of light. Always shake well before use, since some slow separation can occur.
- **Diluted spray:** Once mixed with water, use the spray the same day. Emulsions can separate within 12-24 hours, and microbial growth in water can destabilize the mix. Discard leftovers rather than storing diluted spray.
- **Indicators of instability:** Layering, large oil droplets, or visible separation mean the emulsion is breaking, don’t spray that on plants without mixing well again.

Why it works

Soybean oil sprays at 2% suppressed powdery mildew on roses and tomatoes (1), reduced spider mites by 97-99% (2), and deterred whiteflies (3). Corn oil added control of cucumber mildews (5). Tweens stabilize and spread the oils (4).

Bottom line

- **Concentrate:** 200 mL soybean oil + 200 mL corn oil + 10 mL Tween 20 + 10 mL Tween 80 per liter (or 760 mL + 760 mL + 38 mL + 38 mL per gallon), topped up with water.
- **Spray dilution:** 75 mL concentrate per gallon of water.
- **Final spray:** 0.8% oil, 0.02% Tween 20, 0.02% Tween 80.
- **Shelf life:** Weeks for concentrate (if stored sealed, cool, dark); hours for diluted spray.

This blended, dual-Tween foliar spray is a low-cost, evidence-backed way to add an oil-based control into hydroponic IPM programs.

Coco Coir vs Rockwool in Soilless Crops

Choosing the right substrate is critical in greenhouse hydroponics. Coconut coir (coco peat) has become a renewable alternative to rockwool, and recent studies show it can match or exceed rockwool in many crops. In cucumbers, switching to coir improved leaf area and marketable yield (1). In tomatoes, coir supported higher fruit yield and nutrient uptake than rockwool (2). In leafy greens, lettuce in coco peat produced more biomass than mineral wool or perlite in controlled greenhouse trials (3). Even strawberries have shown equal or better performance in coir compared to rockwool when root-zone aeration is properly managed (4).

A 70:30 coco/perlite blend, one of the best blends to use in soilless cultivation, especially for plants with high oxygen demand

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- **Tomato:** Coir gave higher yields and heavier fruits than rockwool. Plants on coir had significantly greater uptake of potassium and sulfur, translating to larger fruit and more total yield (2).
- **Cucumber:** Coir boosted growth and yield compared to rockwool. Leaf area index and final yield were consistently higher on coir (1).
- **Lettuce:** Coco peat produced ~40% higher leaf biomass than perlite and ~70% higher than mineral wool in one ebb-and-flow greenhouse study (3). In another greenhouse system, rockwool gave the heaviest fresh biomass, but coir produced taller plants and longer roots (5).
- **Strawberries:** Over six months of pot cultivation, strawberries grown in coir matched or outperformed rockwool in shoot dry weight, while showing more stable drainage EC and pH (4). Extension reports and grower

trials further suggest blends of coir with perlite improve aeration and flowering compared to pure coir (6).

Crop Comparison Table

Crop	Rockwool Yield	Coco Coir Yield	Notes/Ref
Tomato	Lower	Higher (2)	Heavier fruit, greater K and S uptake
Cucumber	Lower	Higher (1)	Higher LAI, yield, nutrient levels
Lettuce	Moderate	Higher (3) (5)	Coco peat surpassed mineral wool in one study; rockwool still led in fresh biomass in another
Strawberry	Variable	Equal or higher (4) (6)	Coir stable for EC/pH; blends improve aeration

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Tomatoes on Coir vs Rockwool

In the tomato trial by Xiong et al., coir substrates significantly outperformed rockwool. Plants in coir had higher total fruit yield, greater average fruit weight, and better uptake of key nutrients such as K and S (2). This demonstrates that coir is not just a substitute but a potentially superior medium for greenhouse tomato production.

Cucumbers on Coir vs Rockwool

In greenhouse cucumbers, coir consistently gave higher vegetative vigor and fruit yield. Leaf area index and final yields were significantly higher than on rockwool (1). Nutrient analysis also showed higher Ca, Mg, and Zn contents in coir-grown plants, suggesting coir buffers nutrients more effectively.

Lettuce and Leafy Greens

In Polish greenhouse trials, coco peat lettuce heads produced substantially more leaf biomass than those grown in mineral wool or perlite (3). In contrast, a Philippine hydroponic study found rockwool produced the heaviest fresh biomass, but coco coir gave taller plants and longer roots (5). Together, these results show coir can rival or surpass rockwool, but outcomes depend on system design and cultivar.

Strawberries on Coir vs Rockwool

In Korea, a six-month hydroponic strawberry trial showed that coir matched or outperformed rockwool in shoot dry weight, while maintaining more stable EC and pH in drainage solutions (4). Practical experience also suggests that coir blended with perlite is best for strawberries, as it improves root aeration and prevents waterlogging (6). For crops that have roots that require high oxygenation, perlite amendments are fundamental to the use of coco coir for optimum results.

Coco/Perlite Blends

Many growers prefer mixing coir with perlite to improve aeration. This is especially useful for crops like strawberry, which are sensitive to low oxygen in the root zone. A 70:30 coir:perlite ratio is widely used to combine coir's nutrient buffering with perlite's porosity. **These blends often outperform pure rockwool in practice**.

Summary

Greenhouse research consistently shows that **coir is a strong alternative to rockwool**. Tomatoes and cucumbers perform better on coir, lettuce often produces more biomass, and strawberries grow well provided aeration is managed. Coco/perlite blends add further reliability. For growers aiming to reduce reliance on rockwool, coir and its blends represent a proven, effective option that can sustain or increase yields while offering better root-zone stability.

Recent advances in hydroponic cucumber cultivation: media, irrigation, nutrition and

biostimulants

Cucumber has become a model crop for testing new soilless technologies, with greenhouses adopting alternative substrates, precision fertigation and biostimulants. Over the last decade a series of peer-reviewed studies have clarified what actually shifts growth and yield, and what is still more hype than practice.

A soilless cucumber greenhouse using coco coir.

Substrate choices: coir, waste materials and microbiome effects

The clearest advance is the repeated demonstration that coconut coir outperforms rockwool in cucumbers. A 2022 Heliyon study reported higher leaf area index, greater yields and increased mineral content (Ca, Mg, S, Cl, Zn) in coir compared with rockwool, alongside shifts in fruit amino acids and flavor compounds (1). This is not marginal, it reflects both physiology and quality.

Efforts to cut peat use are also accelerating. A 2025 Scientific Reports trial tested agricultural wastes such as cocopeat, palm peat, vermicompost, sawdust and pumice, finding several blends that produced transplant vigor comparable to peat moss (2). Another study replaced cocopeat with rice straw, sawdust and compost over two seasons; rice straw and coir-rice blends gave the best irrigation water productivity and photosynthesis with yields close to cocopeat (3). In parallel, wood fiber has been tested in combination with peat under staged nitrogen inputs, showing that fiber proportion and N rate jointly determine nutrient uptake efficiency (4).

Beyond performance metrics, substrate strongly shapes the cucumber root microbiome. A 2022 *Frontiers in Microbiology* study showed that different artificial substrates led to distinct bacterial community structures and predicted functions in roots, highlighting that choice of media can influence not only plant nutrition but also microbial dynamics (6).

Finally, biochar-compost amendments are emerging as candidate peat replacements. A 2023 trial demonstrated improved cucumber seedling growth with certain biochar-compost mixes, though physical properties still dictated success (5).

Takeaway: Coir is a proven upgrade over rockwool. Waste-based and fiber blends can substitute part of peat if their hydrophysical traits are tuned. Substrates also rewire root microbiomes, adding another layer to consider.

Irrigation and fertigation: oxygenation and nutrient recipes

Irrigation research has focused on dissolved oxygen. A 2023 Scientific Reports paper tested micro-nano bubble irrigation: raising water DO from ~4 to 9 $mg \cdot L^{-1}$ increased yield and irrigation water use efficiency by ~22%, while boosting vitamin C, soluble solids and photosynthesis (7). The effect is practical, low oxygen is common in dense cucumber crops under low light.

On the nutrient side, hydroponics consistently outperforms soil. A 2025 Scientific Reports comparison found cucumbers in Hoagland solution under soilless culture had taller plants, more flowers and nodes, and 9-19% more fruits than soil-grown controls on alternative formulations (8). These are large differences that underscore the importance of using a complete, balanced solution and not cutting corners on formulation.

Takeaway: Boosting dissolved oxygen is a low-cost irrigation improvement. And nutrient recipes matter, generic soil formulas do not translate well to hydroponics, where Hoagland-type solutions remain robust.

Nutrient interactions: silicon and iron

Element interactions are less visible but no less important. A 2020 *Frontiers in Plant Science* study showed that supplying silicon in hydroponics triggered iron deficiency responses in cucumber, even under adequate Fe, and altered recovery after resupply (9). This is a reminder that “beneficial” elements are not always benign and should be managed carefully, especially when layering biostimulants or micronutrient supplements.

Biostimulants and stress management

Humic substances remain the most tested tools. A 2024 Scientific Reports study under 10 $dS \cdot m^{-1}$ NaCl found that foliar humic acid sprays, especially when combined with grafting onto tolerant rootstocks, improved cucumber growth, antioxidant activity and secondary metabolism relative to untreated controls (10). This reinforces humics as a stress-mitigation option rather than a universal growth booster.

Microalgae are also being trialed. A 2023 MDPI study using *Chlorella vulgaris* suspensions increased root dry biomass of cucumber seedlings in hydroponic culture (11). The shoot response was more variable, but the root effect suggests promise for early growth stages.

Grafting remains a practical biostimulant in the broad sense. A 2023 *Environmental Pollution* study showed that salt-tolerant rootstocks reduced Na transport into cucumber shoots, improving yield and fruit quality under salinity (12).

Takeaway: Humic acids and grafting can buffer salinity stress, while microalgae show root growth potential. None of these replace proper fertigation, but they add resilience once fundamentals are stable.

Practical synthesis

1. **Switch to coir** if you are still on rockwool. Yield and

mineral improvements are consistent (1).

2. **Trial waste substrates cautiously.** Rice straw and fiber blends can work, but only when physical properties are controlled (2) (3).
3. **Oxygenate irrigation water. in NFT systems** Aiming for ~9 $mg \cdot L^{-1}$ DO has measurable payoffs in yield and quality (7).
4. **Use complete nutrient recipes.** Hoagland still outperforms incomplete alternatives (8).
5. **Watch element interactions.** Silicon can complicate iron nutrition in hydroponics (9).
6. **Layer biostimulants for stress, not yield.** Humic acids, grafting and microalgae add tolerance or early root vigor but only after fertigation and media are optimized (10) (11) (12).

Foliar Calcium in Hydroponics

Calcium is essential yet poorly mobile in plants. Young leaves and fruit can go deficient even when solution Ca is adequate, because Ca rides the transpiration stream and is not readily redistributed. Foliar sprays target the tissues that most often lose the race for Ca. Evidence in hydroponics and soilless systems exists, but it is thinner for organic or chelated Ca forms than for simple salts. In this article I will point to some of the research on Ca foliar application, which salts work best and what dosing rates.

Calcium chloride (most commonly available as $CaCl_2.2H_2O$) is the most effective Ca source available for foliar spraying.

What the Research Shows

- **Calcium chloride ($CaCl_2$)** remains the fastest and most reliable for foliar entry. Tomato work directly comparing salts found $CaCl_2$ clearly superior to Ca-citrate (1).
- **Calcium nitrate ($Ca(NO_3)_2$)** is effective and less phytotoxic, but generally requires higher rates to supply the same Ca. Field potato studies showed yield and Ca increases (2).
- **Sorbitol-chelated Ca** has outperformed $Ca(NO_3)_2$ in peanuts, improving leaf Ca and yield (3).
- **Calcium acetate** protected rice from ozone and heat stress better than $CaCl_2$ at equal molar concentrations (4) (5).
- **Calcium lactate** improved water status and yield in lettuce under deficit irrigation (6).
- **Calcium gluconate**, at high concentrations, improved grape cluster quality and storability, especially when combined with chitosan (7).

Practical Rates and Outcomes

Source (salt/product)	Example study & crop	Rate tested (g/gal)	Outcome
Calcium chloride ($CaCl_2$)	Tomato, direct foliar absorption comparison (1)	11–23 g/gal (0.3–0.6% w/v)	Fastest uptake; burn risk above ~20 g/gal
Calcium nitrate ($Ca(NO_3)_2$)	Potato foliar sprays (2)	~15–23 g/gal (0.4–0.6% w/v)	Improved tuber Ca and yield; milder than $CaCl_2$
Sorbitol-chelated Ca (80 g Ca/L stock)	Peanut, two field seasons (3)	≈85 g stock product/gal (6.8 g Ca/gal delivered)	Higher leaf Ca and 12–17% yield gain vs controls and $Ca(NO_3)_2$
Calcium acetate ($Ca(CH_3COO)_2$)	Rice under ozone stress (4), ozone + heat (5)	3.0–3.3 g/gal (5 mM)	Better photosynthesis and yield vs equal-molar $CaCl_2$
Calcium lactate	Lettuce under deficit irrigation (6)	2.8–5.7 g/gal (0.75–1.5 g/L)	Improved water status, antioxidants, yield
Calcium gluconate	Grapes, two seasons (7)	38–76 g/gal (1–2% w/v)	Better fruit quality and storability; best with chitosan

How Fast Does It Work?

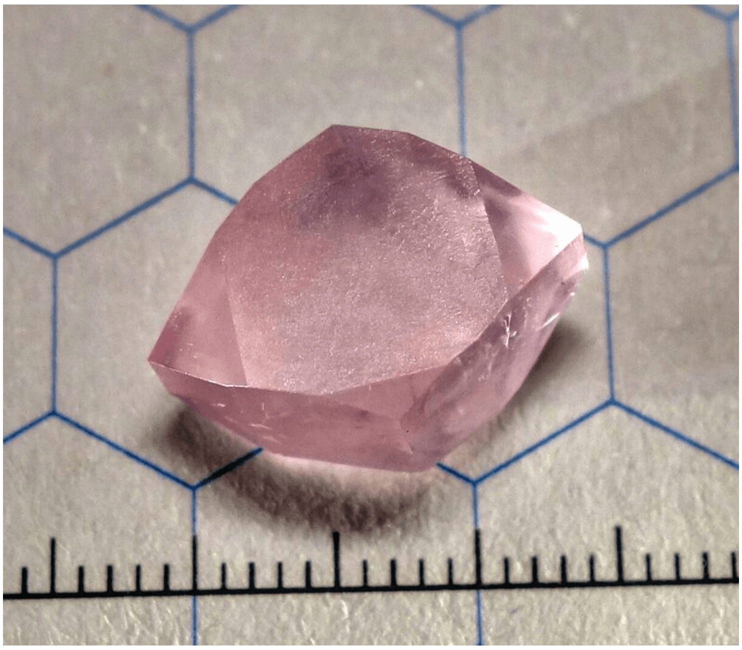
- Leaf Ca increases can be measured within **1–3 days** of spraying $CaCl_2$ (1). Expect **leaf Ca rises in days**, but visible symptom reduction or yield effects in **2–4 weeks of consistent spraying**.
- Stress mitigation (e.g. rice under ozone) required 2 sprays but benefits were seen in yield at harvest, weeks later (4).
- Yield gains in peanut with sorbitol-Ca required repeated sprays across the season (3).

Bottom Line

- **Best for quick entry**: $CaCl_2$, 10–20 g/gal, but can be phytotoxic above ~20 g/gal. Calcium chloride will always be wet (because of how hygroscopic it is) so almost all Ca that falls and remains on leaf surfaces will eventually be taken up (unless it's washed off).
- **Good alternative**: $Ca(NO_3)_2$, 15–25 g/gal, safer on leaves, adds nitrate.
- **Organic/chelated options**: Sorbitol-Ca, calcium acetate, lactate, and gluconate show benefits in specific crops and stress conditions. They often need higher mass per gallon but may reduce leaf burn or improve persistence.
- **Trial first**: Responses vary by crop, environment, and formulation. Test small before scaling.

Do oil-producing crops need extra manganese or just enough?

Manganese is a workhorse micronutrient in plants. It is central to photosystem II, essential for the water splitting chemistry, and a cofactor for several enzymes. Given its importance, plants that produce energetically expensive compounds – like oils – might require more of it to run their machinery, so the threshold question is simple: do oilseed or essential oil crops require manganese above what non oil-producers need, or do they just need standard sufficiency with no premium for “oil production status”?



A manganese sulfate crystal. One of the most commonly used salts to supplement Mn in agriculture.

What the literature actually supports

Recent reviews agree on fundamentals. Plant Mn requirements are driven by core physiology like photosynthesis and redox balance, not by whether a crop partitions carbon to oil, starch or protein. There is no general evidence for a higher Mn setpoint in oil-producing species as a class. Instead, yield and quality respond to correcting deficiency and avoiding toxicity, the same rule that governs non oil-producing crops (1), (2).

Oilseeds

- **Soybean.** Classic work shows severe Mn deficiency reduces seed oil percentage. Once deficiency is corrected, pushing Mn higher does not increase oil; excess Mn depresses growth and yield. In other words, soybean needs adequate Mn, not extra because it is an oilseed (3), (4).
- **Canola/rapeseed.** Liming-induced Mn deficiency is common on high pH soils. Foliar Mn corrects deficiency and restores yield, but applications on adequate plants do not increase oil or seed yield. Again, the benefit is deficiency correction, not a special oil-crop premium (5).

Essential oil crops

- **Water mint (Mentha aquatica).** In solution culture, applying 100 µM Mn sulfate, which is ~5.5 ppm Mn, increased leaf glandular trichome density and essential oil yield relative to a lower Mn background. This shows Mn can modulate secondary metabolism when the baseline is low, but it does not prove that mint requires Mn above typical sufficiency ranges; it shows that deficiency or marginal supply limits oil yield and composition (6).
- **Feverfew (Tanacetum parthenium).** Varying Mg and Mn in controlled media shifted essential oil profiles. Mn

interacted with Mg to alter monoterpene vs sesquiterpene proportions, again indicating composition sensitivity under limited or imbalanced supply rather than a universal need for “extra Mn” (7).

Soilless and hydroponic angle

Hydroponics removes soil redox chemistry, so Mn availability is governed by solution concentration, chelation and pH. Reviews emphasize that plants still follow the same homeostatic rules; oil status does not change the Mn target. In recirculating systems, Mn can drift due to adsorption, precipitation at higher pH and plant uptake, which explains sporadic deficiency in otherwise balanced recipes. Correct the drift and the symptoms resolve; adding more than sufficiency is unnecessary and risks toxicity, especially at low pH (1), (2).

Evidence summary

Crop	System	Mn supplementation rate (ppm Mn)	Outcome on oil yield or composition	Take-home	Study
Soybean	Sand/solution culture	Not specified here in ppm	Severe Mn deficiency lowered seed oil; correcting deficiency restored yield but extra Mn gave no benefit	Adequacy matters, excess does not help	(3), (4)

Crop	System	Mn supplementation rate (ppm Mn)	Outcome on oil yield or composition	Take-home	Study
Canola	Field, calcareous soils	Foliar Mn, rate study	Yield gains only where tissue was Mn-deficient; no gain in Mn-sufficient stands	Target deficiency, not blanket "oil-crop" boosts	(5)
Water mint	Nutrient solution	~5.5	Increased trichome density and essential oil yield from a low-Mn baseline	Adequate Mn is required for EO biosynthesis; no proof of supra-sufficiency need	(6)
Feverfew	Controlled media	Varied Mn, ppm not reported	Mn with Mg shifted monoterpene vs sesquiterpene proportions	Composition responds to Mn status; optimize for sufficiency	(7)

Tissue composition: are oil plants different?

Authoritative reviews catalog Mn uptake, transport and intracellular allocation across species. None propose distinct Mn sufficiency thresholds based solely on oil production. The drivers are photosynthetic demand, transporter regulation and rhizosphere chemistry. Oilseed and essential oil crops display the same deficiency symptoms and toxicity risks as other species. Practically, tissue targets should be set by species-specific sufficiency ranges and growth stage, not by "oil producer" status (1), (2).

Practical stance for soilless growers

1. **Aim for sufficiency, verify with tissue tests.** If chlorosis and interveinal speckling suggest Mn deficiency and tissue Mn is low, bring solution Mn up to a normal range and adjust pH. Do not chase extra Mn for oil content once sufficiency is confirmed (5).
2. **Watch pH and redox.** Slight pH rises or oxidizing conditions can drop available Mn even when total Mn dosing looks fine. Correct pH and renew chelates before increasing Mn concentration (1).
3. **Expect composition shifts near the margins.** In mint and feverfew, Mn status influenced essential oil profile when supply was marginal. That is a signal to maintain adequacy, not a license to overapply (6), (7).

Bottom line

There is no broad academic support for supplementing manganese above normal sufficiency just because a crop produces oil. The consistent finding is boring but useful: correct Mn deficiency and keep supply in a normal, pH-stable window. Oilseed yield and essential oil profiles suffer when Mn is low, and they recover when Mn is adequate. Beyond that, extra Mn does not buy more oil and can cost you growth.

Moringa extract as a

biostimulant in hydroponics

Moringa leaf extract (MLE) is a rather recent addition to the biostimulant market. Below I focus on peer-reviewed work in hydroponic or soilless systems, with attention to yield, quality, toxicity, and dose timing.

Moringa plant leaves, commonly used to create extracts

Evidence and discussion

Hydroponic lettuce. A greenhouse hydroponic study applied MLE at transplant via root dip, then three foliar sprays at 10-day intervals. Marketable yield increased around 30% vs control, leaf area rose, and leaves were less susceptible to Botrytis after harvest. The paper characterized MLE chemistry but treated it mainly as a formulated extract; the schedule, not just the material, clearly mattered [(1)](#).

Tomato in soilless culture. In cherry tomato, four applications of 3.3% w/v MLE, given every two weeks as either foliar or root drenches, improved biomass and increased fruit yield and quality metrics like soluble sugars, protein, antioxidants, and lycopene. 3.3% equals ~33 000 ppm. The same trial compared MLE to cytokinin standards and found MLE competitive when applied on a schedule, not just once (2).

Pepper and tomato under protected cultivation. A peer-reviewed study in a protected environment tested weekly foliar sprays from two weeks after transplant until fruit set. Tomato and pepper showed higher chlorophyll index and fruit firmness, with cultivar-dependent yield gains (3). A separate field-protected trial in green chili parsed delivery method and concentration: seed priming plus foliar MLE at 1:30 v/v (3.3%) delivered the most consistent improvements in growth and a ~46% rise in fruit weight per plant; vitamin C in fruit climbed up to ~50% with foliar 1:20 v/v (5%) (4).

Quality and nitrate in leafy greens. Lettuce grown under glasshouse conditions responded to 6% MLE foliar sprays with higher vitamin C and polyphenols in one season, and lower nitrate accumulation in another. Six percent equals ~60 000 ppm. Effects were season and cultivar dependent, which should temper expectations (5).

Reviews for context. Two recent reviews summarize MLE’s biostimulant activity and mechanisms, with repeated emphasis on dose and frequency dependence and the reality that extraction protocol changes outcomes. They also highlight hormesis and allelopathic risks at higher doses or with sensitive species (6), (7).

Responses are real but system-specific. Yield and quality gains show up most consistently when MLE is scheduled repeatedly at moderate concentrations and aligned with crop phenology.

Reported effects on yield and quality in hydroponic/soilless crops

Crop & system	MLE dose (%)	Application method & timing	Yield effect	Quality effect	Source
Lettuce, perlite hydroponic	Not explicitly stated; applied as standardized aqueous extract	Root dip at transplant, then foliar sprays every 10 days ×3	Marketable yield ↑ ~30% vs control	Higher pigments and total phenolics; postharvest Botrytis severity ↓ 32%	(1)
Cherry tomato, soilless pots	3.3%	100 mL per plant, foliar or root, every 14 days ×4	Fruit yield ↑ 26–38% depending on route	Fruit sugars, protein, antioxidants, lycopene ↑	(2)
Tomato, protected soilless	Not reported	Weekly foliar from 2 WAT to fruit set	Positive, cultivar dependent	Higher chlorophyll index; firmer fruit	(3)
Green chili pepper, protected	3.3%, 5%, 10%	Seed priming ± foliar; best was priming + 1:30 foliar	Fruit weight per plant ↑ ~46% with priming+1:30	Vitamin C ↑ up to ~50% with 1:20 foliar; no change in capsaicin	(4)
Lettuce, glasshouse substrate	6%	Foliar, seasonal trials	Season dependent	Vitamin C and polyphenols ↑ in 2020; nitrate content ↓ in 2019	(5)

Practical dosing windows

Crop	When to apply	Practical note	Source
Lettuce (hydroponic)	Transplant dip, then every 10 days through vegetative phase	Schedule matters at least as much as concentration in this protocol	(1)
Tomato	Every 14 days from early vegetative through early fruiting, foliar or root	3.3% worked across routes; root drenches often gave stronger biomass responses	(2)
Pepper	Seed priming before sowing plus early foliar during preflower to fruit set	Combined priming and 3.3% foliar outperformed single methods	(4)
Tomato and pepper	Weekly foliar from 2 WAT to fruit set	Useful pattern for protected cultivation programs	(3)

Toxicity and limits

Reviews document allelopathic and inhibitory effects at higher doses, with hormesis explaining the switch from stimulation to suppression as concentration increases. Sensitive species and young tissues are at greater risk. Use consistently timed foliar applications for best results, these have been studied much more thoroughly across many more crop species. MLE has inhibitory effects on seed germination and seedling growth for some plants, so refrain from using in very early crop stages unless the species isn’t sensitive (6), (7).

Conclusions

If you want to test MLE in hydroponic or soilless production, use the following guidelines:

1. Use moderate concentrations in the 3-5% range for foliar applications (safer than root applications).
2. Time applications with vegetative growth and preflower phases, repeating at weekly intervals.
3. Expect cultivar and season effects, especially regarding quality.
4. Lookout for toxicity symptoms if using higher concentrations (>5%).
5. Test carefully before using on seedlings or recently rooted cuttings.

Do the basics right and you can get measurable gains in yield and quality with less risk of phytotoxicity. The citations above should help guide your use of this new biostimulant.