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

Crop	Rockwool Yield	Coco Coir Yield	Notes/Ref
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 Cacitrate (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 $CaCl_2$

Source (salt/product)	Example study & crop	Rate tested (g/gal)	Outcome
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?

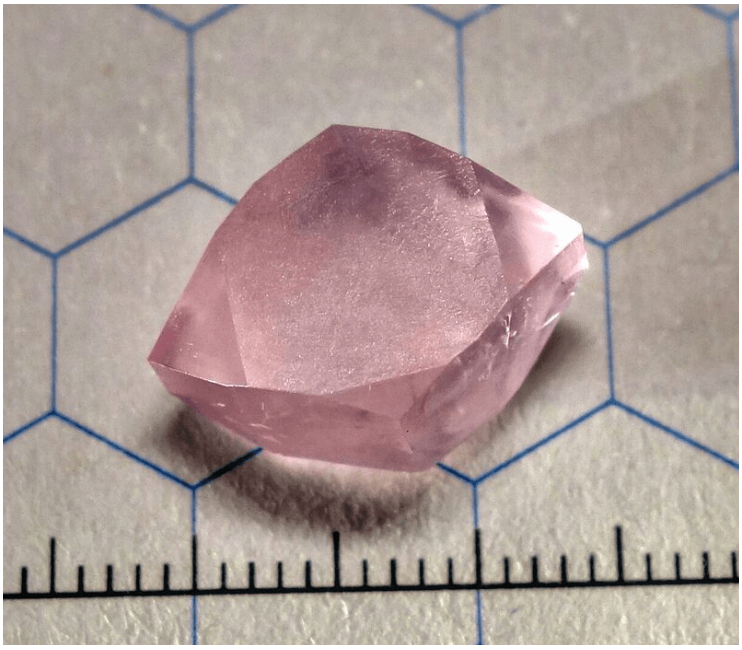
- Leaf Ca increases can be measured within **1–3 days** of spraying $CaCl_2$ (1). Expect **leaf Ca rises in days**, but visible symptom reduction or yield effects in **2–4 weeks of consistent spraying**.
- Stress mitigation (e.g. rice under ozone) required 2 sprays but benefits were seen in yield at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

Crop & system	MLE dose (%)	Application method & timing	Yield effect	Quality effect	Source
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.

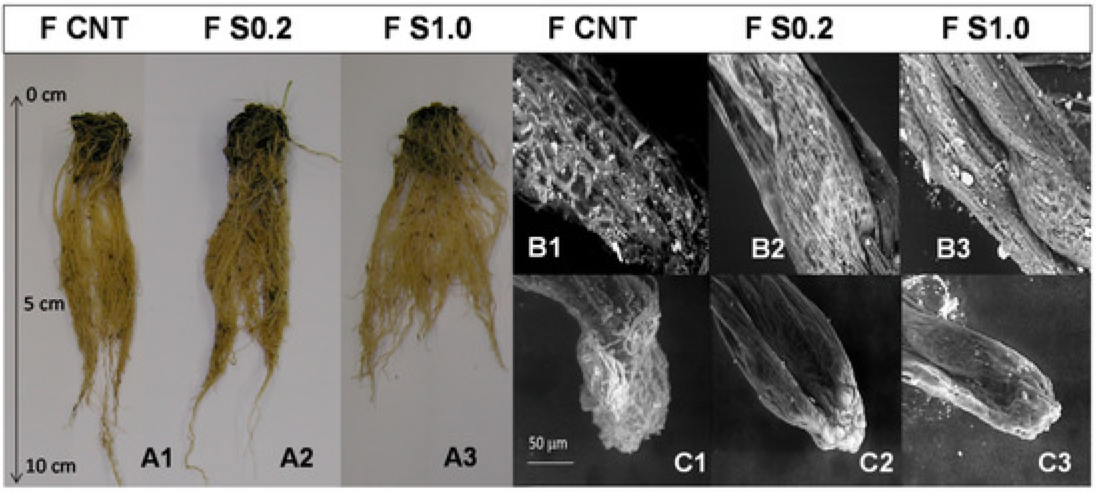
Do the basics right and you can get measurable gains in yield and quality with less risk of phytotoxicity. The citations above should help guide your use of this new biostimulant.

Exogenous Root Applications

of Wetting Agents in Soilless Media

Introduction

Dry peat, coir, rockwool or bark mixes can become water repellent, which creates uneven moisture and nutrient delivery around roots. Wetting agents reduce surface tension and restore wettability by improving water contact with hydrophobic surfaces, an effect well documented for organic growing media used in horticulture (6). In soilless systems, exogenous root applications are used to correct dry-back, stabilize irrigation performance, and improve nutrient distribution. This post reviews what has been tested, how these agents affect mineral nutrition, water uptake, yield and quality, known toxicity limits, and realistic application rates.



Effect of surfactants on roots. Taken from (7)

Evidence and discussion

Types tested

Most root-zone wetting agents in horticulture are nonionic surfactants such as alcohol ethoxylates, block copolymers, or organosilicone derivatives; anionic formulations are less common for routine root use due to higher phytotoxic risk, while cationic types are generally avoided; amphoteric agents are used less frequently but appear in some products. The role of wetting agents to counter water repellency in organic media is supported by a comprehensive review of wettability mechanisms and amendments (6).

Water uptake and distribution

In rockwool and coir, adding a nonionic surfactant to the fertigation stream at doses from 2 to 20 000 ppm showed that a **minimal** dose could be sufficient: **2 ppm** increased easily available water by more than 600 percent, while higher concentrations gave no extra benefit (1). Across peat, coir, and bark, wetting agents improved hydration efficiency, although severely dry materials retained some hydrophobic pockets that were not fully overcome by surfactant treatment (2).

Mineral nutrition

In a melon crop on rockwool and reused coco fiber, weekly fertigations with a nonylphenol ethoxylate at about **1000 ppm** reduced nitrate and potassium losses in drainage and increased potassium uptake, while leaving total water use and pH unchanged (3). In lettuce, fertigation with a nonionic organosilicone-type surfactant at **200 ppm** and **1000 ppm** improved nutrient use efficiency without increasing yield, indicating better capture of applied nutrients for the same biomass and specifically in field trials with a methyl-oxirane nonionic surfactant. Direct lettuce evidence of improved nutrient use efficiency and root-zone wetting with **~200–1000**

ppm doses comes from an in-field trial using a nonionic methyl-oxirane surfactant (6) and is detailed further under quality effects below.

Yield and quality

Yield responses depend on whether water distribution was limiting. In lettuce, the nonionic surfactant improved nutrient use efficiency but did **not** increase marketable yield under well-watered conditions. Quality can benefit: lettuce fertigated with a nonionic methyl-oxirane surfactant at **~1000 ppm** showed a significant reduction in leaf nitrate accumulation compared with controls, alongside indications of shallower, more uniform wetting of the upper root zone (6).

Persistence and accumulation

Repeated use matters. In sand models, a polyoxyalkylene polymer surfactant (PoAP) sorbed to particles and **increased hydrophobicity** after repeated applications, whereas an alkyl block polymer (ABP) maintained or improved wettability and did not leave a hydrophobic residue. Chemistry dictates long-term behavior, so product choice is critical (4).

Toxicity

There is a hard ceiling for some agents. Hydroponic lettuce exposed to the anionic detergent Igepon showed acute root damage at **≥250 ppm**, with browning within hours and growth suppression, although plants recovered after the surfactant degraded in solution (5). Practical takeaway: avoid harsh anionic detergents and keep any surfactant well below known toxicity thresholds.

Tables

Table 1. Water behavior in soilless substrates after root-zone wetting agents

Study (Ref)	System and media	Surfactant and dose	Key outcome
(1)	Rockwool and coir, new and reused	Nonionic surfactant, 2–20 000 ppm	**2 ppm** raised easily available water by >600 percent; higher doses gave no additional gain
(2)	Peat, bark, coir under different initial moistures	Commercial wetting agent, low to high	Hydration efficiency improved across materials, but extremely dry media retained some hydrophobic zones

Table 2. Nutrient dynamics, yield, quality, and safety

Study (Ref)	Crop and system	Regime and dose	Observed effect
(3)	Melon in rockwool and reused coco	Weekly fertigation at ~1000 ppm	Lower nitrate and potassium leaching, higher K uptake, no change in water use or pH
(6)	Lettuce, fertigated field context	Nonionic surfactant ~200–1000 ppm	Improved nutrient use efficiency; neutral yield response; reduced leaf nitrate at higher dose
(4)	Sand columns, repeated applications	PoAP vs ABP, repeated dosing	PoAP accumulated and increased hydrophobicity; ABP maintained or improved wettability

Study (Ref)	Crop and system	Regime and dose	Observed effect
(5)	Lettuce in hydroponics	Anionic detergent ≥250 ppm	Acute root phytotoxicity at and above 250 ppm; recovery after degradation of the agent

Practical rates

In closed hydroponic or recirculating fertigation, start conservatively. Research showing benefits without injury typically used **~50–1000 ppm**, with several studies centering on **~1000 ppm** weekly pulses in drip systems, or **~200–1000 ppm** continuous-equivalent dosing in trials on leafy greens (3) (6). Very low concentrations can already fix wettability issues, as the 2 ppm result illustrates (1). Always monitor for foaming, root browning, or oily films. Avoid cationic disinfectant-type surfactants at the root zone and keep anionic detergents far below the **250 ppm** lettuce toxicity threshold (5). Choose chemistries that do not accumulate with repeated use (4).

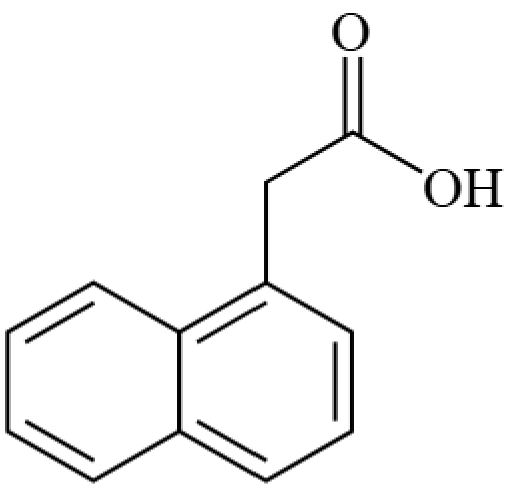
Conclusion

For soilless production, exogenous root applications of wetting agents are a precise way to restore uniform wetting, stabilize nutrient delivery, and improve nutrient use efficiency. Expect neutral yield when irrigation is already optimal, but better quality in leafy greens via lower leaf nitrate, and less nutrient loss in drain when media are reused or prone to channeling. Use the lowest effective ppm, prefer nonionic chemistries validated in horticultural systems, and be wary of products that persist or sorb to media. Done right, wetting agents are a small, high-leverage tweak that keeps the entire root zone working for you, not against you.

Root-applied auxins in hydroponics: where they help, where they don’t

Introduction

Auxins can modulate root architecture, fruiting and stress responses. In hydroponic and substrate soilless systems, exogenous **root-zone** applications at very low ppm sometimes boost yield or quality. Push the dose and you flip the response. Below I review peer-reviewed work on widely grown crops, focusing on species, timing, exact dosages converted to ppm, and toxic thresholds. Where possible I prioritize reviews to frame context, but yield data come from primary trials.



Model representation of the NAA molecule, a very commonly used auxin in plant culture.

Evidence & discussion

Sweet pepper. Two lines of evidence exist. First, fertigation with a commercial IBA product at **0.4 percent** active (4000 ppm in the stock) applied **weekly from early fruit development** at **0.5 L ha^{-1}** outperformed **1.0 L ha^{-1}**, increasing marketable yield while improving root mass and water and nutrient uptake in perlite culture (1). Second, a separate trial compared **root fertigation vs foliar** using a formulation containing **6.75 g L^{-1} NAA** and **18 g L^{-1} NAA-amide**. The fertigation rate was **0.6 mL L^{-1}** of product in the solution, equal to **~4 ppm NAA** plus **~10.8 ppm NAA-amide** per application; foliar used **0.4 mL L^{-1}** or **~2.7 ppm NAA** plus **~7.2 ppm NAA-amide**. Early and total yield were higher with fertigation, while foliar favored some quality traits like firmness and soluble solids (5). Practical read: peppers respond to root-zone auxin in the **single-digit ppm** range, but more is not better.

Melon. The same IBA approach that helped pepper flopped in melon. In perlite greenhouse culture, **0.4 percent IBA** applied **weekly** at **0.5 or 1.0 L ha^{-1}** did **not** improve yield or water or nutrient relations. Authors concluded it is not an effective tool for commercial melon in soilless culture (2). Species matter.

Strawberry. In long recirculating systems, autotoxic phenolics depress growth and fruiting. A **one-time root or crown dip** in NAA **before transplant** at **5.4 µM** NAA, which is **~1 ppm**, mitigated autotoxicity and restored flower and fruit numbers compared with untreated plants. A higher **54 µM** dose, about **10 ppm**, was less effective (3). Timing was everything.

Toxic thresholds from hydroponic seedlings. While not a yield trial, maize in nutrient solution shows the margins. IBA at **10^{-11} M** is **~0.000002 ppm** and stimulated root growth, but **10^{-7} M** is **~0.02 ppm** and significantly stunted primary root elongation and biomass. The same hormone switches from helpful to harmful across four orders of magnitude (4). That narrow window explains why melon trials can miss and pepper trials can hit. For broader context on root-zone biostimulation via fertigation programs, see this review (6).

Tables

Table 1. Positive responses to exogenous auxin at the root zone in soilless crops

Crop & system	**Auxin and delivery**	**Dose in root zone (ppm)**	**Timing**	**Outcome**
Sweet pepper, perlite	IBA 0.4 percent product via fertigation	Stock is **4000**; applied **0.5 L ha^{-1} weekly**	From early fruit development	Higher marketable yield at 0.5 vs 1.0 L ha^{-1}; improved root mass and water and nutrient uptake (1)
Sweet pepper, soilless	NAA + NAA-amide via fertigation	**~4** NAA + **~10.8** NAA-amide per application	Weekly during production	Higher early and total yield vs foliar; foliar favored firmness and °Brix (5)

Crop & system	Auxin and delivery	Dose in root zone (ppm)	Timing	Outcome
Strawberry, recirculating hydroponics	NAA root or crown dip	**~1** optimal; **~10** less effective	One time at transplant	Mitigated autotoxic yield loss; restored flower and fruit counts under closed reuse (3)

Table 2. Null results and toxic thresholds

Crop or context	Auxin & delivery	Threshold or tested dose (ppm)	Timing	Result
Melon, perlite greenhouse	IBA 0.4 percent via fertigation	Stock **4000**; **0.5 or 1.0 L ha⁻¹ weekly**	Season-long	No improvement in yield or water or nutrient relations (2)
Maize seedlings, hydroponic assay	IBA in solution	**0.000002** stimulatory vs **0.02** inhibitory	Continuous exposure	Root growth stimulation at ultra-low ppm but marked stunting by **0.02 ppm** (4)

Conclusion

Root-applied auxins are not a silver bullet. They can raise yield or preserve quality, but only when dose and timing line up with the crop’s physiology. Peppers respond to **single-digit ppm** root fertigation with higher early and total yields, while melons do not. Strawberries benefit from a **~1 ppm** pre-plant dip that preempts autotoxicity, whereas **~10 ppm** underperforms. Hydroponic seedling work reinforces the risk: **~0.02 ppm** IBA already suppresses maize roots. The safe play is to trial low, crop-specific ppm near published values, apply at the stage that matters, and stop if marketable yield does not move. If you treat auxins like a nutrient and “turn them up,” they will punish you. If you treat them as a precise signal, they can pay off.

Recent findings in hydroponic and soilless strawberries: a data-first look at the last decade

Strawberry in controlled environments is not short on opinions. Research from the past 10 years has given us a lot of information on strategies to increase yields and reduce costs. Below I synthesize recent findings, aiming to provide you with practical information that can help you improve your crop. I focus first on mineral nutrition, then biostimulants, exogenous hormone applications, and pruning or cultural practices. When concentration units were not reported in ppm, I converted them. Where authors only gave mL L^{-1} of a commercial product, I report ppm v/v and, when possible, ppm of active ingredients.

A picture of a soilless strawberry crop

What the evidence says

Mineral nutrition that consistently improves output

1. Stage-specific K:N balance matters more than one static recipe. A greenhouse pot trial in soilless bags across three cultivars found that running a higher K:N balance in vegetative growth, then lowering it in production, delivered the best overall performance. Their S2 program (growth K:N 2.6, production K:N 1.0) raised yield by 30 percent and improved firmness and shelf-life metrics compared to other balances, with equal seasonal totals of N, P, K, Ca, Mg across treatments. This is one of the clearest, practical levers reported for soilless production in the last decade (1).
2. Absolute NO_3^- and K setpoints still matter, but the optimum is not "more is better". A hydroponic study that orthogonally varied nitrate and potassium in soilless strawberries showed that 15 mM NO_3^- increased yield

while higher K favored nutraceutical quality. Converting their molarities to ppm: 9, 12, 15 mM NO_3^- equal 126, 168, 210 ppm N as nitrate and 558, 744, 930 ppm NO_3^-, while 5, 7, 9, 11 mM K^+ equal 196, 274, 352, 430 ppm K. The highest yields occurred at the upper end of their NO_3^- range, with quality improving as K approached 430 ppm K. Takeaway: push N during heavy fruiting if you can keep flavor in check, and use K to tune quality targets (2).

3. Simply cranking K in water-culture will backfire. A 2025 deep-water culture trial that stepped K from 117 to 348 ppm at constant 77 ppm N found no yield benefit and, in some cases, reduced fruit size and total yield as K rose. Translation: chasing high EC by piling on K is noise, not signal, in DWC strawberries (3).
4. The nitrate fraction can be used as a steering tool without changing total N. A 2025 soilless study that varied the percentage of total N supplied as nitrate from 0 to 100 percent across three cultivars showed meaningful shifts in plant N status and leachate pH, offering a route to manage uptake and alkalinity without changing ppm N. This is more about stability and diagnosis than raw yield, but it is actionable in recirculating systems (4).
5. System choice is not neutral. A 129-day greenhouse comparison found a coir-based substrate system substantially outperformed three water-culture systems (NFT, vertical stacked flow, aeroponics) for total yield and resource-use efficiency in ‘Florida Brilliance’ and ‘Florida Beauty’. If your priority is marketable kilograms per square meter, substrate is still the safe bet unless you have a very strong reason to go water-culture (5).

Biostimulants with greenhouse soilless data

Two solid greenhouse papers in soilless bags make this practical:

• A nutrient-limitation stress trial in soilless ‘Elsanta’ tested 10 foliar biostimulants. Several treatments improved marketable yield and fruit quality under low fertility. Doses were applied as labeled $mL\ L^{-1}$; I report them as ppm v/v. Effects were strongest for specific protein hydrolysates and seaweed extracts, with chitosan showing quality gains rather than yield spikes (6).

• A head-to-head in substrate culture directly compared commercial plant biostimulants and synthetic auxins. The best biostimulant program matched or exceeded auxin-based fruit set under the tested conditions, and the paper fully discloses active contents for the auxin products, which lets us convert to ppm actives for fair comparison (7).

Exogenous hormone applications

Soilless strawberry papers using PGRs are fewer than field studies, but the 2024 greenhouse comparison above provides what growers need: dose-disclosed auxin programs in substrate bags, with yield and quality outcomes. The synthetic auxin formulation Auxyger was listed at $6.7\ g\ L^{-1}$ NAA + $16.9\ g\ L^{-1}$ NAD. At $0.5\ mL\ L^{-1}$, that is 3.35 ppm NAA and 8.45 ppm NAD actives. In that trial, the best protein hydrolysate program rivaled or beat this auxin program on yield while improving certain quality attributes, which makes a case for biostimulant-first strategies where regulations or buyer specs frown on PGR residue (7).

Pruning and culture practices with measurable, repeatable gains

• Runner control increases yield in everbearing cultivars under tabletop tunnel production. Bi-weekly runner removal in 'Favori' increased total and marketable yield per plant and improved average berry size, while partial defoliation reduced both. This is not a subtle effect; it is sink management and it pays off (8).

• Planting density in greenhouse substrate is a yield vs. cull tradeoff, not a free lunch. A two-season soilless trial in troughs found 5 to 15 cm in-row spacing maximized commercial fruit and profitability for 'Pircinque', but the densest spacings increased small and discarded fruit percentage. If labor for canopy management is tight, 10 to 15 cm is the saner operating point (9).

• System selection again: when in doubt, choose substrate if your KPI is kilograms. The 2025 greenhouse head-to-head is clear that coir-based substrate outperformed water-culture for both yield and resource efficiency in their conditions (5).

Mineral nutrition highlights in soilless strawberries

Study & system	Factor	Setpoints converted to ppm	Observed effect
Preciado-Rangel 2020, soilless culture (2)	$NO3^-$ and K in solution	$NO3^-$ at 126, 168, 210 ppm N (558, 744, 930 ppm $NO3^-$). K at 196, 274, 352, 430 ppm K	Higher $NO3^-$ increased yield, higher K improved nutraceutical quality; best yields at 210 ppm N with K toward 430 ppm K.

Study & system	Factor	Setpoints converted to ppm	Observed effect
Ries 2025, deep-water culture (3)	K at constant 77 ppm N	117, 194, 271, 348 ppm K	Increasing K above 117 ppm did not improve yield or fruit size; higher K often reduced fruit size and yield.
Yafuso 2025, soilless substrate (4)	Percent of total N as nitrate	0 to 100 percent of total N as $NO3^-$ at a fixed total N (ppm not changed)	Adjusting nitrate fraction shifted foliar N and leachate pH, offering control without changing ppm N.
Nakro 2023, greenhouse soilless (1)	K:N balance over time	Growth phase K:N 2.6, production phase K:N 1.0 (ratios)	Program raised yield 30 percent and improved firmness and shelf-life vs other balances.

Biostimulants in soilless strawberries

Product or molecule	Type	Dose used in study (ppm)	Cultivar & system	Observed effect	Source	Notes

Product or molecule	Type	Dose used in study (ppm)	Cultivar & system	Observed effect	Source	Notes
Protein hydrolysate (Trainer)	Amino acid hydrolysate	5000 ppm v/v (5 mL L^{-1})	‘Elsanta’ in peat-based substrate	Increased marketable yield and improved quality under nutrient limitation	(6)	Labeled concentration is mass per kg; ppm v/v reported for transparency.
Seaweed extract	Ascophyllum-based	2500 ppm v/v (2.5 mL L^{-1})	‘Elsanta’ in substrate	Yield and antioxidant gains under low fertility	(6)	Product-label dose.
Chitosan solution	Biopolymer	10000 ppm v/v (10 mL L^{-1})	‘Elsanta’ in substrate	Quality improvements more than yield	(6)	DDA: NR, molar mass: NR in paper.
Protein hydrolysate program	Amino acid hydrolysate	5000 ppm v/v (5 mL L^{-1})	Greenhouse substrate bags	Matched or exceeded auxin program on yield while improving specific quality traits	(7)	See auxin row for direct comparison.

Exogenous hormones tested in soilless conditions

Active(s)	Class	Dose as actives (ppm)	Product dose	Cultivar & system	Observed effect	Source
NAA + NAD	Synthetic auxin + cofactor	3.35 ppm NAA + 8.45 ppm NAD calculated from 6.7 g L^{-1} NAA + 16.9 g L^{-1} NAD at 0.5 mL L^{-1}	0.5 mL L^{-1}	Greenhouse substrate bags	Increased fruit set and yield vs water control, but best protein hydrolysate program was competitive on yield with added quality benefits	(7)

Pruning and cultural practices in soilless systems

Practice	Setting	Quantified outcome	Source
Bi-weekly runner removal	Everbearing ‘Favori’ in tabletop tunnel	Higher total and marketable yield and larger berries vs keeping runners; defoliation reduced yield	(8)
In-row spacing 5 to 15 cm	Greenhouse troughs, soilless substrate	Highest commercial yield and profitability with 5 to 15 cm, but denser plantings increased culls; 10 to 15 cm safer if labor is limited	(9)

Practice	Setting	Quantified outcome	Source
System choice: substrate vs water-culture	Greenhouse, coir substrate vs NFT, vertical, aeroponics	Substrate system delivered the highest yield and best resource-use efficiency in both tested cultivars	(5)

Practical summary

• If you run substrate culture, start with a sane base recipe and adopt a two-phase K:N strategy. Push K:N in vegetative growth to build canopy and sink capacity, then lower K:N in production to support sustained fruiting. The 2.6 then 1.0 K:N program is the best documented template right now and lifted yield by 30 percent in greenhouse soilless conditions (1).

• For absolute targets during heavy fruiting, do not be shy about 200 ppm N as nitrate if fruit flavor is maintained, and keep K in the 350 to 430 ppm range to pull quality without sacrificing mass. That is where the 2020 hydroponic NK grid saw the best balance (2).

• Water-culture is unforgiving with K. Above roughly 120 to 200 ppm K in DWC at moderate N, returns were negative in 2025 work, so treat “more K” as a risk factor rather than a lever in water-culture strawberries (3).

• Biostimulants can be yield-positive under stress and can stand toe-to-toe with low-dose auxin programs in substrate. If you need a conservative starting point, weekly foliar protein hydrolysate at 5000 ppm v/v is the most replicated choice across the soilless greenhouse literature summarized here (6), (7).

• Exogenous auxins at single-digit ppm actives work, but they are not automatically superior to a strong biostimulant program in greenhouses. If you use auxins, be precise about actives. The 0.5 mL L^{-1} Auxyger rate equals 3.35 ppm NAA + 8.45 ppm NAD. Compare like with like, not mL of product (7).

• Cultural practices still pay the bills. Remove runners on a schedule in everbearers and do not defoliate unless you enjoy losing yield (8). Pick a density you can actually manage. If labor is tight, 10 to 15 cm spacing is a rational compromise in tabletop or trough systems (9). If you are choosing systems with yield as the top KPI, substrate culture remains the safest option in 2025 greenhouse data (5).

Recent advances in the cultivation of CEA tomatoes: evidence from 2015–2025

Hydroponic tomato yields are already high, yet many operations still leak performance through nutrient scheduling, canopy design, and stress control. Below is a blunt, data-driven synthesis for controlled environments based on recent scientific studies. The pattern is consistent: stabilize nutrition and irrigation first, then layer biostimulants or hormones only where trials show a payoff.

A soilless cherry tomato crop. *Photo courtesy of Pakistan Hydroponics*. You can watch their farm here.

Mineral nutrition and solution management

A 2024 greenhouse study across six cultivars found that a constant nutrient concentration program matched yield and improved size distribution compared with stage-based ramps when EC was well controlled (1). A 2023 review distills current best practice for recirculating systems, stressing stage-appropriate EC, ion ratios that avoid antagonisms, and disciplined monitoring in closed loops (2).

Closed systems are viable when sanitation and monitoring are tight. A greenhouse comparison showed closed hydroponics achieving similar yields with better water and fertilizer use efficiency than open run-to-waste setups (3). Calcium balance still matters. Whole-plant experiments showed that simply pushing calcium does not prevent blossom-end rot and that imbalances can backfire, so keep Ca adequate and balanced rather than excessive (4).

Irrigation and pruning practices that scale

Partial root-zone drying and moderate deficit irrigation remain the most defensible water-saving tactics in greenhouses. Grafted tomatoes under PRD or deficit regimes saved 30 to 40 percent water with only minor yield penalties and sometimes higher fruit mineral concentrations (5).

On canopy design, a low-truss high-density approach can raise kilograms per square meter. In a hydroponic sub-irrigated trial with the indeterminate hybrid Rebeca, the top treatment was two trusses per plant at 11.1 plants per square meter, reaching 22.61 kg per square meter in 134 days without harming fruit quality (6).

Biostimulants with signal, not hype

Seaweed extracts and chitosan have the most consistent tomato evidence in soilless systems.

A greenhouse study in inert substrates showed that foliar seaweed extract at 100 000 to 200 000 ppm improved chlorophyll, gas exchange, and fruit quality indices. Silicon at 75 ppm (as sodium silicate) increased firmness and yield per plant in a palm-peat mix. Effects were substrate and dose dependent, so you must calibrate to your product and spray volume per area (7). A 2022 review synthesizes similar benefits for seaweed extracts under salinity stress, with gains tied to photosynthesis and ion homeostasis rather than magic bullets (8).

For chitosan, a 2025 greenhouse study on Floradade and Candela F1 tested 500, 1000, and 2000 ppm foliar programs. Higher rates improved growth and physiology, with cultivar-specific responses. Product specs like degree of deacetylation and molar mass were not reported, so do not assume equivalence across suppliers (9).

Exogenous hormones: targeted, not blanket

If fruit set is the bottleneck during heat or low pollen viability, exogenous hormones can help. In protected cultivation of cv. Srijana, a conservative foliar program of GA3 at 50 ppm with NAA at 25 ppm increased fruit set and total yield. The response surface penalized higher rates, reminding you that timing and dose are critical (10). For mechanism and limits, a 2022 review explains how auxin and gibberellin signaling induce parthenocarpy in tomato and why misuse leads to malformed fruit (11).

Summary tables

Table 1. Mineral nutrition and system practices with yield impact in CEA tomatoes

Factor	Cultivar or type	Dose or setting (ppm)	Observed effect	Source
Constant vs stage-based nutrient supply	Six cultivars, greenhouse	Program choice rather than dose	Constant feed matched yield and improved size distribution	(1)
Nutrient solution management review	General CEA	Program design	Best practice for EC, ion ratios, and closed-loop monitoring	(2)

Factor	Cultivar or type	Dose or setting (ppm)	Observed effect	Source
Closed vs open hydroponics	Determinate tomato, greenhouse	System choice	Closed loop improved water and fertilizer efficiency with comparable yield	(3)
Calcium balance	Modern genotypes	Balanced Ca supply	Lower BER risk depends on overall ion balance, not brute Ca	(4)
Partial root-zone drying and deficit irrigation	Grafted tomato, greenhouse	Irrigation scheduling	30 to 40 percent water savings with minor yield penalties	(5)

Table 2. Biostimulants in soilless tomatoes

Biostimulant	Cultivar or type	Application	Dose (ppm)	Observed effect	Source
Seaweed extract	Cherry tomato, greenhouse substrates	Foliar	100 000 to 200 000	Improved physiology and fruit quality indices under stress	(7)

Biostimulant	Cultivar or type	Application	Dose (ppm)	Observed effect	Source
Silicon as sodium silicate	Cherry tomato, greenhouse substrates	Foliar	75	Increased firmness and yield per plant in palm-peat mix	(7)
Chitosan (medium MW, commercial)	Floradade and Candela F1	Foliar, multiple sprays	500, 1000, 2000	Improved growth and physiological performance, cultivar dependent	(9)
Seaweed extract review	Multiple tomato types	Seed or foliar in soilless culture	Various	Stress tolerance and modest yield gains under salinity	(8)

Table 3. Exogenous hormone programs with documented yield or set effects

PGR	Cultivar or type	Application	Dose (ppm)	Observed effect	Source
GA3 + NAA	Srijana, protected cultivation	Foliar during flowering	GA3 50, NAA 25	Increased fruit set and total yield; higher rates underperformed	(10)
Auxin and GA context	Tomato, general	Mechanistic review	N/A	Explains parthenocarpy induction and risks of misuse	(11)

Practical takeaways

Do not chase clever ramps before you can hold EC steady. A constant, well-tuned feed can match yield and improve size distribution when the rest of the system is under control (1), (2). Closed loops pay only if you earn them with monitoring and sanitation (3). Low-truss high-density recipes push kg per square meter, provided irrigation and nutrition meet the faster sink demand (6). Seaweed extracts and silicon can help under stress, but responses are product and substrate specific. Chitosan works, yet cultivar and formulation matter, so trial first (7), (8), (9). Hormones are scalpels for set problems, not a replacement for climate and pollination management (10), (11).

How to easily lower the costs of your Athena nutrient regime

You can make your Athena schedule much cheaper by replacing the pH up products with simple raw salts. Branded pH management and buffering products like Athena Balance and Athena Pro Balance are, at their core, just sources of potassium bases delivered in carbonate or silicate form. They are however, very over priced for what they are and can be a high percentage of the overall cost of running these nutrient regimes. By understanding their labels and safety data sheets, we can replicate these formulations with commodity salts, achieving equivalent nutritional and pH adjusting outcomes at a fraction of the cost.

AgSil 16H, a very common base used to prepare potassium silicate solutions.

Athena Pro Balance can be replaced with Potassium Carbonate

The powdered Pro Balance product is likely nothing more than high-purity potassium carbonate (K_2CO_3), usually 98.5–100% pure. Chemically, K_2CO_3 contains ~68% K_2O-equivalent by weight, which is exactly what the Athena Pro Balance label reflects. This means you don't need to blend or dilute anything to make a replacement, simply sourcing food-grade or fertilizer-grade potassium carbonate is sufficient. You can dose it directly as you would the branded powder, bearing in mind it is strongly alkaline and should be added to water with care. Storage should be in sealed HDPE containers to avoid caking from atmospheric moisture.

Athena Blended Balance (liquid) can be replaced with an AgSil 16H solution

The liquid Balance label shows 2% K_2O. AgSil 16H, a common potassium silicate source, contains 32% K_2O and ~53% SiO_2. To reproduce the K_2O content of Athena Balance, you need to dilute AgSil at the correct ratio:

- Target is 2% K_2O.

- Required fraction = 2 / 32 = 0.0625.
- This means 6.25% (w/w) AgSil in water.

Translated to a practical recipe, this equals **236.6 g of AgSil 16H per US gallon of solution** (3.785 L), topped up with RO water (must be RO or distilled water). Dissolve the AgSil slowly with vigorous mixing, as potassium silicate is highly viscous and alkaline. The result is essentially identical in potassium concentration to the branded Balance, with the added benefit of supplying soluble silica (~1.55% Si in the solution).

Improving stability with KOH
One common issue with potassium silicate solutions is their tendency to polymerize or precipitate over time, especially at lower concentrations or in the presence of divalent cations. To mitigate this, adding a small amount of potassium hydroxide (KOH) helps maintain a strongly alkaline environment that discourages silica gelation. For the recipe above, **adding 1 g of KOH per gallon** of solution is a simple way to improve stability during storage. This will not significantly change the K_2O content but will keep the solution more stable and easier to handle.

Cost Analysis
Beyond the chemistry, cost is the main driver for making these substitutions. Let’s look at a ballpark comparison based on typical retail prices (USD, 2025):

Product	Retail Price	Equivalent Raw Material	Raw Material Price	Cost per Gallon of Finished Equivalent
Athena Pro Balance (powder)	~$7 per lb	Potassium carbonate	~$2 per lb	Replacement is more than 3x cheaper

Athena Balance (liquid)	~$20-40 per gallon	AgSil 16H + 1 g KOH	~$6.4 per lb AgSil, ~$5 per lb KOH (~3$ AgSil + 1c of KOH per gal)	Replacement costs is around 10x cheaper

For the Balance liquid in particular, the price difference is striking: the branded gallon runs around $20-40, while the equivalent solution made from AgSil 16H plus a pinch of KOH comes out to under $3 per gallon, even at retail chemical pricing. The Pro Balance substitution is less dramatic in absolute terms but still represents substantial savings over time.

Take-home message

Replacing Athena Pro Balance is as simple as sourcing potassium carbonate, while Athena Balance can be reliably reproduced with a potassium silicate solution prepared from AgSil 16H plus a small stabilizing addition of KOH. For growers comfortable working with raw salts, this substitution strategy provides full control, predictable composition, and significant cost savings while providing a drop-in replacement for one of the most expensive parts of the Athena nutrient line.