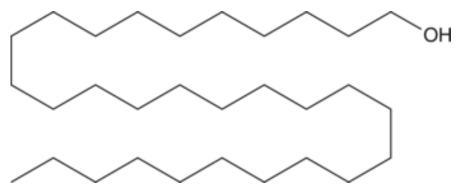
Triacontanol Foliar Sprays in Soilless Culture: Formulation and Application

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 μ M 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)

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.

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 &	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 1 26–38% depending on route	Fruit sugars, protein, antioxidants, lycopene f	(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 1 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	<u>(5)</u>

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	<u>(2)</u>
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	<u>(3)</u>

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.

Iodine in Hydroponic Crops: An Emerging Biostimulant

Introduction

Iodine sits in a weird spot in plant nutrition. It is essential for humans, not officially essential for higher plants, yet low, well chosen doses often push crops to perform better in controlled systems. The key is dose and form. Get

either wrong and you tank growth. Get them right and you can see yield and stress-tolerance gains that are economically meaningful. Recent reviews lay out both the promise and the pitfalls, so let's cut through the noise and focus on agronomically relevant hydroponic and soilless work only. (1)



Potassium iodide, one of the most common forms used to supplement iodine in hydroponic culture.

Why iodine can behave like a biostimulant

Mechanistically, iodine at trace levels appears to influence redox balance and stress signaling and can even become covalently bound to plant proteins. Proteomic evidence has shown widespread protein iodination, and plants deprived of iodine under sterile hydroponics grow worse until micromolar-range iodine is restored. That does not make iodine "essential" in the strict sense, but it explains why tiny doses can trigger outsized responses. (2)

Form matters

Across multiple hydroponic tests, iodide is absorbed faster and is more phytotoxic than iodate. In basil floating culture, growth was unaffected by roughly 1.27 ppm iodine as KI or 12.69 ppm iodine as KIO_3 , but KI above about 6.35 ppm iodine cut biomass hard, while KIO_3 needed far higher levels to do the same. That is a practical takeaway for nutrient solution design. Favor iodate when you are exploring a new crop or cultivar. (3)

Evidence from hydroponic and soilless crops

Lettuce

A classic water-culture study ran 0.013 to 0.129 ppm iodine in solution and saw no biomass penalty while leaf iodine rose predictably. Iodide enriched tissue more than iodate at equal iodine, which is useful if your target is biofortification, not just a biostimulant effect. (4)

Under salinity, iodate becomes more interesting. In hydroponic lettuce with 100 mM NaCl, about 2.54 to 5.08 ppm iodine as KIO_3 increased biomass and upregulated antioxidant metabolism, which is exactly what you want in salty recirculating systems. Push higher and the benefits fade. (5)

Strawberry

Hydroponic strawberry responded to very low iodine. Iodide at or below 0.25 ppm and iodate at or below 0.50 ppm improved growth and fruit quality, while higher levels reduced biomass and hurt fruit quality metrics. You do not have much headroom here. (6)

Basil

Greenhouse floating culture trials on sweet basil showed cultivar-specific tolerance but the same pattern every time. KI starts biting growth above single-digit ppm iodine, while KIO_3 is far gentler at comparable iodine. Antioxidant capacity trends are cultivar dependent, so do not generalize "more phenolics" as a guarantee of better growth. (7)

Tomato

Tomato is where yield effects get real. In growth-chamber work, fertigation with iodate at roughly 6.35 to 12.69 ppm iodine increased fruit yield by about 30 to 40 percent in a small-fruited cultivar. In a greenhouse trial with a commercial hybrid, much lower iodine in solution, around 0.025 to 1.27 ppm as KIO_3 , still improved plant fitness and mitigated part of the salt penalty. Dose tolerance depends on the system and the genotype, so copy-pasting numbers between cultivars is a bad idea. (8)

Cabbage

Hydroponic Chinese cabbage tested 0.01 to 1.0 ppm iodine as KI or ${\rm KIO_3}$. Uptake and partitioning behaved differently by species and form. The practical read is that both forms work for biofortification within that band, but I would still lean iodate first for safety. (9)

Working ranges seen in hydroponic or soilless trials

Crop	System	Iodine form used	Dose range tested in literature (ppm as I)	Observed direction of effect
Lettuce	Water culture	Iodide and iodate	0.013 to 0.129	Neutral on biomass, strong tissue enrichment at all doses tested
Lettuce under salinity	Hydroponic with 100 mM NaCl	Iodate	~2.54 to 5.08	Biomass increased, antioxidant system activation
Strawberry	Hydroponic	Iodide and iodate	Beneficial at or below 0.25 (I-) and 0.50 (IO3-)	Growth and fruit quality improved at low doses, declines above
Basil	Floating culture	Iodide and iodate	Safe near 1.27 as KI, 12.69 as KIO ₃ ; toxicity above ~6.35 as KI	KI far more phytotoxic than KIO₃ at equal iodine
Tomato	Substrate fertigation and growth chamber	Iodate	~0.025 to 12.69 depending on setup	Yield and stress tolerance improved within study-specific bands
Cabbage	Hydroponic	Iodide and iodate	0.01 to 1.0	Both forms accumulated; response form- dependent

Practical setup that does not wreck a crop

Start with iodate. It is consistently less phytotoxic in solution culture than iodide at the same iodine level. Use iodide later only if you have a clear reason. (7)

Leafy greens

Conservative exploratory band: 0.03 to 0.10 ppm iodine in solution during vegetative growth. If you are running saline conditions, you can test up to about 2.5 to 5.1 ppm as iodate for stress mitigation, but do not do this blind outside a salinity trial. (4) (5)

Strawberry

Keep solution iodine low. Try 0.05 to 0.25 ppm as iodide or 0.10 to 0.50 ppm as iodate. Expect quality shifts alongside biofortification, and expect penalties if you push higher. (6)

Basil

If you work with KI, do not exceed about 1.3 ppm iodine without a reason and tight monitoring. With KIO3, you have more headroom, but benefits are not guaranteed at the higher end. (7)

Tomato

In substrate systems, exploratory fertigation bands that have shown positive responses run roughly 0.025 to 1.27 ppm iodine as iodate for commercial cultivars. Higher doses around 6.50 to 12.50 ppm have improved yield in small-fruited genotypes under controlled conditions, but those are not starting points for a commercial house. (8)

Cabbage and other Brassicas

0.01 to 1.0 ppm works for biofortification trials in solution culture. Track form-specific uptake. (9)

Common failure modes

- 1. **Using iodide when you should have used iodate.** Iodide is more phytotoxic in water culture. If you switch to iodide, cut the ppm accordingly and watch plants closely. (7)
- 2. Copying doses between crops or between stress contexts.

 Lettuce under salt stress tolerated and benefited from multi-ppm iodate that would be overkill in non-saline runs. (5)
- 3. Chasing biofortification at the expense of growth. Strawberry is very sensitive; the window for improvement is narrow and easy to overshoot. (6)
- 4. **Assuming universality.** Tomato shows real yield gains, but the best range depends on cultivar and system. Validate locally. (8)

Crop	Best form to start	Trial band to test next (ppm as I)	Notes you should not ignore
Lettuce	KIO ₃	0.03-0.10 for routine runs; up to 2.5-5.1 only in salinity trials	Tissue enrichment is easy at sub-ppm; benefits need stress context
Strawberry	KI or KIO ₃	0.05-0.25 as KI; 0.10-0.50 as KI03	Quality improved at low levels; penalties above
Basil	KIO ₃	0.5-3.0	KI becomes risky above low single digits

Crop	Best form to start	Trial band to test next (ppm as I)	Notes you should not ignore
Tomato	KIO ₃	0.025-1.27 in commercial substrate; leave 6.5-12.5 to controlled trials	Verify by cultivar; watch fruit quality metrics
Cabbage	KIO ₃	0.05-0.5	Uptake is efficient; track partitioning by organ

Final word

Iodine can behave like a biostimulant in hydroponics and soilless systems, but only if you respect its razor-thin margin between helpful and harmful. Start small, prefer iodate, and validate on your own cultivars and systems instead of trusting a one-size-fits-all recipe. If you need a broader framework for running precise biofortification trials in soilless production, recent reviews are clear about why controlled systems are the right place to do this work. (9)