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:

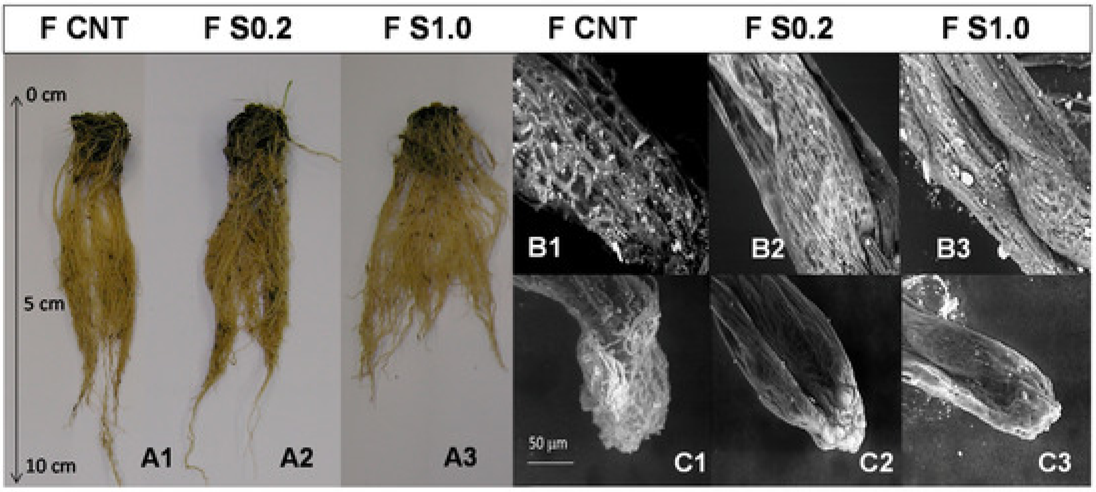
1. Use moderate concentrations in the 3-5% range for foliar applications (safer than root applications).
2. Time applications with vegetative growth and preflower phases, repeating at weekly intervals.
3. Expect cultivar and season effects, especially regarding quality.
4. Lookout for toxicity symptoms 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.

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

Study (Ref)	System and media	Surfactant and dose	Key outcome
(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
(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.

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)	NO_3^- and K in solution	NO_3^- at 126, 168, 210 ppm N (558, 744, 930 ppm NO_3^-). K at 196, 274, 352, 430 ppm K	Higher NO_3^- increased yield, higher K improved nutraceutical quality; best yields at 210 ppm N with K toward 430 ppm K.
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 NO_3^- 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
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)

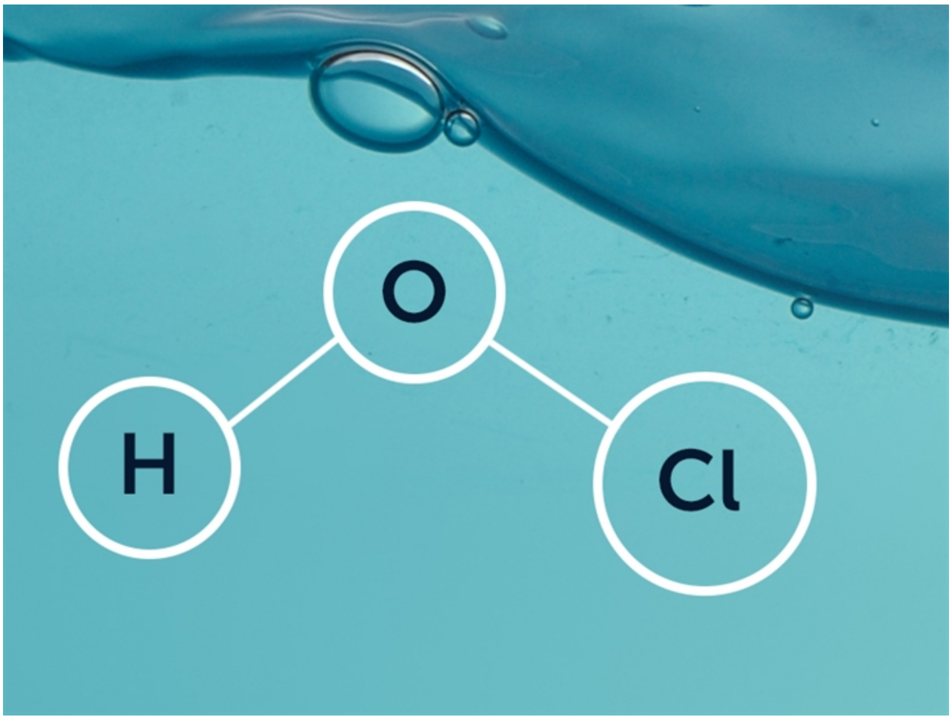
Practical takeaways

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 prepare your own hypochlorous acid cleaner using bleach

During the past couple of years, cleaning products based on hypochlorous acid derived from electrolysis have become popular in the hydroponic industry. This is because, in the USA – per 40 CFR § 180.940 – hypochlorous acid products containing less than 200 ppm of active chlorine are exempted from many manufacturing and handling requirements and are therefore easy to produce and dispense to hydroponic growers. While more dilute, the formulations produced can often be much more stable than more concentrated products and still provide satisfactory cleaning results in a hydroponic reservoir. However, the products carry a lot of additional cost compared to traditional sodium hypochlorite based cleaning products.

This is because more needs to be used – as they are more dilute – and the products themselves are often much more expensive.



Graphic representation of hypochlorous acid

In this post, I want to help you create a solution analogous to many commercially available, electrolytically derived hypochlorous acid cleaners, using products that are easily available and low cost. The resulting solution is – for all intents and purposes I can think of – equivalent to electrochemically derived hypochlorous acid, since the hypochlorite ion becomes protonated at low pH, generating the required substance during the preparation process. To create this formulation, I relied on the following documents and the scientific literature they referenced (1, 2, 3).

Important note. *Hypochlorous acid is unstable in highly concentrated solutions. Increasing the concentration of the formulation below significantly can lead to potentially dangerous releases of chlorine gas when the pH is lowered. Work in a well ventilated area and do not exceed the concentration amounts recommended in this preparation. Work responsibly and make sure to read all the MSDS of the substances used and use appropriate personal protection* *equipment.*

These are the things you will need for the preparation :

1. Freshly bought Clorox (7.4%). The solution should not be older than one week.
2. A 20 mL syringe.
3. Monopotassium Phosphate (MKP).
4. Sodium Chloride (table salt will do).
5. Magnesium Sulfate.
6. Sodium Tripolyphosphate.
7. A calibrated pH meter.
8. A scale to weigh salts, +/-0.1g.
9. A scale to weigh water +/-0.1kg
10. Distilled or RO water (tap water will not work). Distilled is preferable.
11. Clean plastic, air-tight container (at least 1gal) to store the resulting solution. The container should be opaque.

This is the procedure you should follow for the preparation of the hypochlorous acid solution (values for ~1.2 gallon, can be scaled up for larger amounts):

1. Calibrate your pH meter using fresh pH 4 and pH 7 buffer solutions.
2. Fill the container with 3.6 kg of distilled water, this will be referred to as the solution.
3. Weigh and add 0.5g of Sodium Chloride to the solution.
4. Stir until fully mixed.
5. Weigh and add 0.1g of Sodium tripolyphosphate to the solution.
6. Stir until fully mixed.
7. Measure 11mL of Clorox and add it to the solution. If you’re working with a bleach solution with concentration other than 7.4%, multiply 11mL by 7.4 and divide by your

concentration to obtain the amount you should use in mL (for example, if using a 6% bleach solution, you would require 11*7.4/6 = 13.56mL).

8. Stir until fully mixed.
9. Weigh 0.5g of Monopotassium phosphate and add to the solution.
10. Stir until fully mixed.
11. Measure the pH of the mix. If the pH is >7 slowly add and fully mix small portions (~0.1g) of monopotassium phosphate until the pH is in the 6.5-7 range. Take at least 1 minute between additions to ensure the pH has stabilized before adding more.
12. Weigh and add 3.5g of Magnesium sulfate to the solution
13. Stir until fully mixed.
14. Add 0.9kg of water.
15. Confirm final pH is in the 6-7 range, you can add more monopotassium phosphate if needed to drop the pH.

This should provide you with a solution that is stable in the medium term and has the active chlorine concentration of a formulation similar to products like Athena Cleanse. The expected concentration of hypochlorous acid should be around 0.02% (200ppm). It can be used from 2 to 10mL/gal of hydroponic nutrient solution, depending on the severity of the problems that need to be solved. *For overall maintenance and the solution of minor infections, dosages of 5mL/gal should be more than adequate*. The Magnesium Sulfate and Sodium Chloride are added as stabilizing agents, while the mono potassium phosphate is added as a pH buffering agent and the sodium tripolyphosphate is a cleaning agent meant to keep irrigation lines clean (it can be omitted if this is not a concern). *Note that the contributions of the mineral ions to a formulations nutrition at the applied concentrations are negligible.*

Please do let me know if you have any questions about the above preparation. **If you have prepared it, please let us know how it went in the comments below!**

A guide to different pH up options in hydroponics

When is pH up needed?

The control of pH in hydroponics is critical. Most commonly, we need to decrease the pH of our solutions as most nutrients will initially be at a higher than desired pH. This is especially true when tap water or silicates are used, as both of these inputs will increase the overall pH of hydroponic nutrients after they are prepared. In recirculating systems, pH will also tend to drift up due to the charge imbalance created by the high active uptake of nitrate ions carried out by most plant species. For a discussion on pH down options, please read my previous post on this topic.

However, there are certain circumstances where the pH of hydroponic solutions needs to be increased. This can happen when tap water or silicates are not used or when plants decrease pH due to an aggressive uptake of some cations. Plants like tomatoes can do this when grown in solutions with high potassium contributions, as they will actively uptake these nutrients to the point of changing pH balance. Excess ammonium can be another common cause for pH decreases in hydroponic solutions that require the use of pH up solutions.

Potassium hydroxide pellets, the most powerful pH up option available to growers

With this in mind, let’s discuss the pH up options that are available in hydroponics. I only considered substances that are soluble enough to create concentrated solutions, such that they can be used with injector systems.

pH up options

Sodium or potassium hydroxide (NaOH, KOH)

These are the strongest. They are low cost, can be used to prepare highly concentrated solutions and will increase the pH most effectively. They are however unstable as a function of time because they react with carbon dioxide from the air to form sodium or potassium carbonates. This means that their concentrated solutions need to be kept in airtight containers and that their basic power will decrease with time if this is not the case. Additionally, these hydroxides are extremely corrosive and their powder is an important health hazard. Dissolving them in water also generates very large amounts of heat – sometimes even boiling the water – which makes their usage more dangerous. Although desirable when basic power is the most important short term concern, I recommend to avoid them giving their PPE requirements and the lack of long term stability.

When these hydroxides are used, potassium hydroxide is the recommended form, as potassium hydroxide is both more basic and a plant nutrient, while excess sodium can cause problems with plant development. However, sodium hydroxide might be more desirable if it can be obtained at a particularly low price and small additions of sodium are not a concern.

Potassium silicate

This is a soluble form of silicon that is stable at high pH values. While solutions of potassium silicate by itself can be prepared and used as a pH up option, it is usually stabilized with a small addition of potassium hydroxide to take the pH of solutions to the 11-12 range. Potassium silicate contributes both potassium and silicon to hydroponic solutions – both important nutrients – and its use can be more beneficial than the use of pure potassium hydroxide. While silicates are less basic and more mass is required for the same pH buffering effect, the preparation and handling can often be much simpler than those of potassium hydroxide.

Note that potassium silicate solutions are also unstable when left in open air, as they will also react with atmospheric carbon dioxide to generate potassium carbonate. It is also worth noting that not all potassium silicates are the same, when looking for a highly soluble potassium silicate for hydroponics, make sure you get potassium silicates that have higher K/Si ratios. Usually ratios of at least 1.05 are required (make sure you convert both K and Si to their elemental forms, as most of these products report K as K_2O and Si as SiO_2).

Potassium carbonate (K_2CO_3)

This basic salt is stable in air, has less demanding PPE requirements and can also be used to prepare concentrated solutions (more than 1g of potassium carbonate can be dissolved per mL of water). Because of its lower basicity compared to potassium hydroxide, more of it also needs to be used to increase the pH of a hydroponic solution. However, solutions of it are stable, so there is no concern for their stability or changes to its basic power.

Another advantage given by potassium carbonate is that – contrary to the previous two examples – it does increase the buffering capacity of the solution against pH increases, due to the addition of carbonate to the solution. As carbon dioxide is lost to the air at the pH used in hydroponics, the pH of the solutions tends to drift up, this means that the carbonate addition makes the pH more stable in solutions where the pH is being constantly pushed down. This is all part of the carbonic acid/bicarbonate equilibrium, which also helps chemically buffer the solutions at the pH used in hydroponics.

Overall potassium carbonate is one of my favorite choices when there is a downward drift of pH in recirculating solutions.

Potassium phosphate (K_3PO_4)

Another weak base, potassium phosphate, can be used to prepare concentrated solutions and increase the pH in hydroponic solutions. While its solubility and basicity are lower than that of potassium carbonate, it does provide additional phosphorus that can buffer the pH of the solution. This happens because mono and dibasic phosphate ions are anions that be taken up by plants, therefore decreasing the pH. While phosphates can help chemically buffer the hydroponic solution against pH increases, for decreases the phosphate buffer is ineffective as the pKa of the relevant equilibrium is 7.2.

An issue with potassium phosphate is that it provides large contributions of K to solution. These potassium additions can be quite counter productive if the cause of the pH drift towards the downside is related to potassium uptake.

Potassium Citrate/Lactate/Acetate

Basic organic salts of potassium can also be used to increase the pH. These are all much weaker than even the carbonate and phosphate bases mentioned above and relatively large additions are required for even a moderate immediate effect in pH. However, since these anions are actively taken up by microbes, the microbial metabolism of these ions will create a longer term effect on pH. A moderate addition of potassium citrate can only cause a small increase of pH in the short term, with a larger increase happening during the following 24 hours.

A disadvantage is that these anions can also lead to explosions in bad microbe populations if the environment does not have an adequate microbial population. When these salts are used, adequate microbial inoculations need to be carried out to ensure that the microbes that will proliferate will not be pathogenic in nature.

Protein Hydrolysates

While hydrolysates themselves can have an acidic pH when put in solution, their microbial metabolism aggressively increases the pH of solutions in the medium term. This means that these hydrolysates should not be used for immediate pH adjusting, as they will tend to decrease pH further in the very short term, but they can be used as a more long term management option.

As with the above organic salts, their use also requires the presence of adequate microbial life. If you neglect to properly inoculate the media before their addition, then pathogens can also make use of these amino acids to proliferate.

Combinations are also possible

As with the case of pH down options, some of the best solutions for a problem come when several of the above solutions are combined. For example the use of potassium rich pH up solutions in microbe containing soilless media can often cause pH drift issues related with potassium to worsen. For this reason, it can be desirable in these cases to prepare pH up solutions that include protein. This means that you reduce the pH fast but then you have a residual effect from protein metabolism that helps you fight the pH increase as a function of time.

However not all pH up drifts are caused by potassium, as in the case of plants where pH up drift happens due to low nitrate uptake (for example some flowering plants that stop producing a lot of additional leaves during their flowering stage). In these cases potassium based pH up solutions cause no additional issues and combinations of potassium carbonate and potassium phosphate might be best.

Choose according to your goals

As in most cases, the best solution will depend on your circumstances. Think about whether you’re just adjusting the pH of your initial solutions or whether you need to compensate for a constant drift, whether microbial life is present and whether you’re concerned with the accumulation of any substances in a recirculating solution. Once you consider these factors and review the above solutions, you should be able to find the pH up solution that is better suited to your particular needs.

Are you using a pH up? Let us know why and which one you’re using in the comments below!

A one-part hydroponic nutrient formulation for very hard water

What is water hardness?

There are many parameters that determine the quality of a water source. Water that has a composition closer to distilled water is considered of a higher quality, while water with many dissolved solids or high turbidity is considered low quality. Calcium carbonate, magnesium carbonate, calcium sulfate and calcium silicate are some of the most common minerals that get dissolved into water as it runs through river beds and underground aquifers. The carbonates and silicates will make water more basic, will increase the water's buffering capacity and will also increase the amount of magnesium and calcium present in the water.

Water hardness is determined experimentally by measuring the amount of Calcium and Magnesium in solution using a colorimetric titration with EDTA. Although both Calcium hardness (specific amount of Ca) and Magnesium hardness (specific amount of Mg) are measured, total water hardness (the sum of both) is the usually reported value. The result is often expressed as mg/L of $CaCO_3$, telling us how much $CaCO_3$ we would require to get a solution that gave the same result in the EDTA titration.

The Calcium and Magnesium present in water sources with high hardness is fully available to plants – once the pH is reduced to the pH used in hydroponics – and it is therefore critical to take these into account when formulating nutrients using these water sources. *It is a common myth that these Ca and Mg are unavailable, this is not true.*

What about alkalinity?

Water alkalinity tells us the equivalent amount of calcium carbonate we would need to add to distilled water, to get water that has the same pH and buffering capacity. An alkalinity value of 100 mg/L of $CaCO_3$ does not mean that the water has this amount of carbonate, but it means that the water behaves with some of the chemical properties of a solution containing 100mg/L of $CaCO_3$. In this particular case, it means that the water requires the same amount of acid to be titrated as a solution that has 100mg/L of $CaCO_3$.

Water sources with high hardness will also tend to have high alkalinity as the main salts that dissolve in the water are magnesium and calcium carbonates. Since these carbonates need to be neutralized to create a hydroponic solution suitable to plants, the anion contribution of the acid that we will use to perform the neutralization needs to be accounted for by the nutrient formulation.

An example using Valencia, Spain

Valencia, in the Mediterranean Spanish coast (my current home), has particularly bad water. Its water has both high alkalinity and high hardness, complicating its use in hydroponics. You can see some of the characteristics of the water below (taken from this analysis):

Name	Value	Unit
Calcium	136	ppm
Magnesium	42	ppm
Chloride	103	ppm

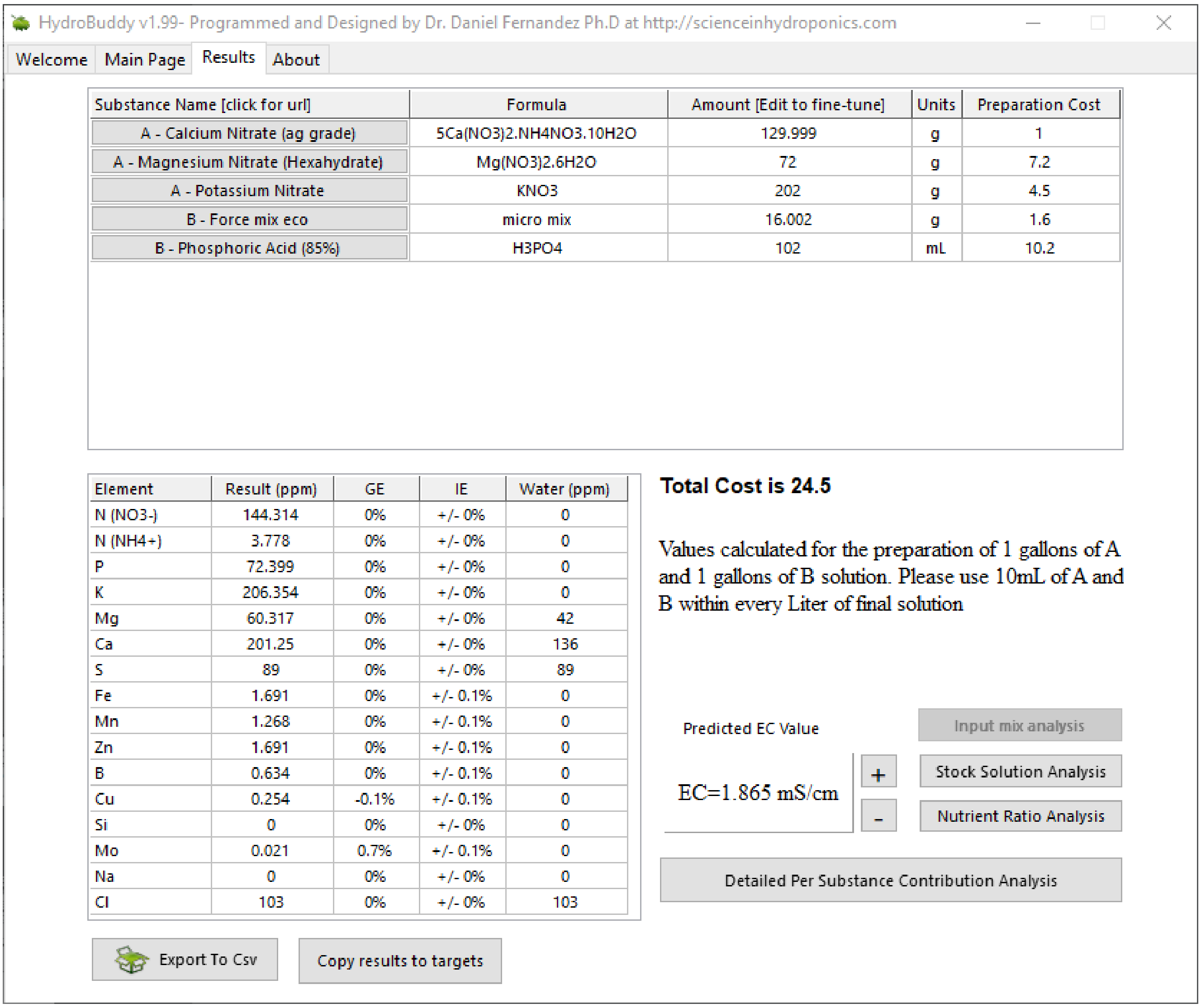
Sulfur	89	ppm
pH	7.6	
Alkalinity	240	mg/L of $CaCO_3$

Typical water quality values for water in Valencia, Spain.

Hard water creates several problems. Since Calcium nitrate is one of the most common sources of Nitrogen used in hydroponics, how can we avoid using Ca nitrate? Since we have more than enough. Also, how can we neutralize the input water so that we can make effective use of all the nutrients in it without overly increasing any nutrient, like P, N or S, by using too much of some mineral acids?

Creating a one-part solution for very hard water

HydroBuddy allows us to input the characteristics of the input water into the program so that we can work around them while designing nutrient solutions. To get around the above mentioned problems – but still ensure I could easily buy all the required chemicals – I decided to use a list of commonly available fertilizers. I used Calcium Nitrate, Magnesium Nitrate, Potassium Nitrate, Phosphoric acid (85%) and a micro nutrient mix called Force Mix Eco (to simplify the mixing process). This micronutrient mix is only available to people in the EU.



HydroBuddy v1.99- Programmed and Designed by Dr. Daniel Fernandez Ph.D at http://scienceinhydroponics.com

Welcome | Main Page | Results | About

Substance Name [click for url]	Formula	Amount [Edit to fine-tune]	Units	Preparation Cost
A - Calcium Nitrate (ag grade)	5Ca(NO3)2.NH4NO3.10H2O	129.999	g	1
A - Magnesium Nitrate (Hexahydrate)	Mg(NO3)2.6H2O	72	g	7.2
A - Potassium Nitrate	KNO3	202	g	4.5
B - Force mix eco	micro mix	16.002	g	1.6
B - Phosphoric Acid (85%)	H3PO4	102	mL	10.2

Element	Result (ppm)	GE	IE	Water (ppm)
N (NO3-)	144.314	0%	+/- 0%	0
N (NH4+)	3.778	0%	+/- 0%	0
P	72.399	0%	+/- 0%	0
K	206.354	0%	+/- 0%	0
Mg	60.317	0%	+/- 0%	42
Ca	201.25	0%	+/- 0%	136
S	89	0%	+/- 0%	89
Fe	1.691	0%	+/- 0.1%	0
Mn	1.268	0%	+/- 0.1%	0
Zn	1.691	0%	+/- 0.1%	0
B	0.634	0%	+/- 0.1%	0
Cu	0.254	-0.1%	+/- 0.1%	0
Si	0	0%	+/- 0%	0
Mo	0.021	0.7%	+/- 0.1%	0
Na	0	0%	+/- 0%	0
Cl	103	0%	+/- 0%	103

HydroBuddy results to create 1 gallon of 1:100 nutrient solution for Valencia's very hard water.

Note that we use absolutely no phosphates or sulfates, since the solution already contains more than enough sulfur (89 ppm) and we need to add all the Phosphorus as phosphoric acid to be able to lower the alkalinity. I determined the amount of P to add by setting P to zero, then using the "Adjust Alkalinity" to remove half of the alkalinity of the water using phosphoric acid. This is more than enough P to be sufficient for higher plants. The above nutrient ratios should be adequate for the growth of a large variety of plants, although they are a compromise and not ideal for any particular type of plant.

Since we are adding no sulfates and the pH of the solution is going to be very low (because of the phosphoric acid), we can add all of these chemicals to the same solution (no need to *make A and B solutions). The values in the image above are for the preparation of 1 gallon of concentrated solution. This solution is then added to the water at 38mL/gal of tap water to create the final hydroponic solution.*

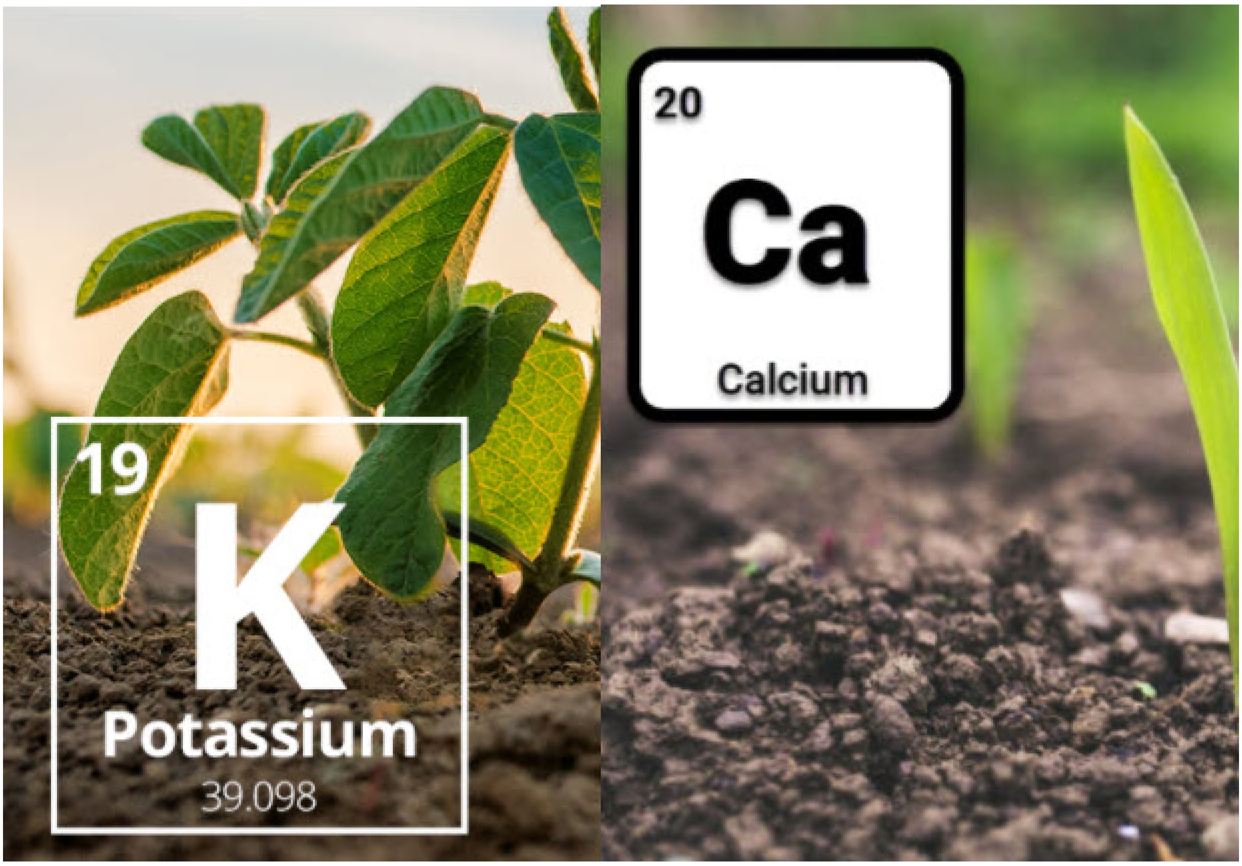
Does it work?

I have experimentally prepared the above concentrated solution – which yields a completely transparent solution – and have created hydroponic solutions I am now using to feed my home garden plants. After adding to my tap water – initial pH of 7.6 – I end up with a solution at a pH of 5.6-5.8 with around 1.5-1.8mS/cm of electrical conductivity. The plants I'm currently growing – basil, rosemary, chives, mint, malabar spinach and spear mint – all seem to thrive with the above solution. I am yet to try it on any fruiting crops, that might be something to try next year!

Are you growing using hard water, have you prepared a similar one-part for your hard-water needs? Let us know what you think in the comments below!

The Potassium to Calcium ratio in hydroponics

To have a healthy hydroponic crop, you need to supply plants with all the nutrients they need. One of the most important variables that determine proper nutrient absorption, is the ratio of Potassium to Calcium in the nutrient solution. These two elements compete between themselves and have different absorption profiles depending on the environment, and the plant species you are growing. For this reason, it is important to pay close attention to this ratio, and how it changes with time, in your nutrient solution. In this post, we are going to examine peer-reviewed research about this ratio and how changing it affects the growth, quality, and yield of different plant species.



Two vital elements that compete against each other. Their ratio is fundamental to maximize yields and changes depending on the plant species, environmental conditions and absolute concentrations used

Two ions with very different properties

Potassium and Calcium are very different. Potassium ions have only one positive charge and do not form any insoluble salts with any common anions. On the other hand, calcium ions have two positive charges and form insoluble substances with a large array of anions. This creates several differences in the way plants transport and use these two nutrients.

While potassium is transported easily and in high concentrations through the inside of cells, Calcium needs to be transported in the space between cells and its intracellular concentration needs to be very closely regulated. Calcium can also only be transported up the plant – from roots to shoots – while potassium can be transported up and down as it pleases.

Calcium transport – happening around cells – is heavily dependent on transpiration, which is what causes water to flow through this space. Potassium transport is not so closely related to transpiration, as it can move directly through the inside of cells in large amounts, which means it can be actively transported through the plant in an effective manner.

Note that the above is a broad over-simplification of Potassium and Calcium transport. If you would like to learn more about this topic, I suggest reading these reviews (1,2).

Competition between K and Ca

Potassium and Calcium are both positively charged, so they do compete to a certain extent. The competition is both because they compete for anions – which they need to be paired with for transport – and for the use of electrochemical potential, which they take advantage of to get transported across membranes. However, they do not have the same transport mechanisms, so the competition is limited.

Table 5. Interaction between EC and K:Ca ratio on nutrient concentration (g kg^{-1}) YFEL of cv. Red Mignonette 3 weeks (maturity) and 3YL 2 and 3 weeks after transplanting

EC ($dS\ m^{-1}$)	K:Ca	YFEL-wk 3 K	YFEL-wk 3 Ca	YFEL-wk 3 Mg	YFEL-wk 3 P	3YL wk 2 K	3YL wk 3 K
0·4	1·00:3·50	31·4	11·1	6·1	7·2	46·5	33·6
0·4	1·25:1·00	81·2	10·8	3·4	8·5	64·5	59·9
0·4	3·50:1·00	84·5	10·2	3·7	8·4	66·9	63·6
1·6	1·00:3·50	89·9	13·2	3·6	8·7	65·2	61·6
1·6	1·25:1·00	90·5	10·8	3·5	8·7	64·5	65·2
1·6	3·50:1·00	97·8	9·8	4·0	8·6	65·7	65·1
3·6	1·00:3·50	86·1	7·3	3·9	9·6	59·7	59·2
3·6	1·25:1·00	94·4	10·1	3·0	8·5	60·8	62·6
3·6	3·50:1·00	96·6	4·1	3·3	8·7	67·4	64·4
	l.s.d.[A]	9·9	2·3	0·8	0·9	5·2	4·1

Table taken from this article (3)

The table above illustrates this point. This study (3) looked into different K:Ca ratios in the growing of lettuce and the effect these ratios had on yield, tip burn, and nutrient concentrations in tissue. You can see that at low total concentrations (0.4 mS/cm EC) the K in tissue is very low when the amount of Ca is high relative to K, while at higher EC values (1.6 mS/cm EC), the K concentration remains basically unaffected, even if the Ca concentration is 3.5 times the K concentration. While Ca competes effectively with K when the absolute concentration of both is low, this competition of Ca becomes quite weak as the concentration of K and Ca increase. At very high concentrations (3.6 mS/cm EC), the potassium does start to heavily outcompete the Ca, especially when the K:Ca ratio is high (3.5x).

The above is also not common to all plants. For some plants, the competition of Ca and K actually reverses compared to the results shown above. However, it is typical for low and high absolute concentration behaviors to be different, and for the influence of K or Ca to become much lower in one of the two cases.

Optimal K:Ca ratios

The K:Ca ratio has been studied for many of the most popularly grown plants in hydroponics. The table below shows you some of these results. It is worth noting, that the results that maximized yields, often did so at a significant compromise. For example, the highest yield for lettuce came at the cost of a significantly higher incidence of inner leaf tip burn. In a similar vein, the highest yields in tomatoes, at a 3:1 ratio, came at the cost of additional blossom end rot problems. This is to say that, although these ratios maximized yields, they often did so with consequences that wouldn't be acceptable in a commercial setup. For lettuce, 1.25:1 proved to be much more commercially viable, while still giving high yields.

Ref	Plant Specie	Optimal K:Ca
4	Rose	1.5:1
5	Tomato	3:1
6	Tomato	1.7:1
7	Marjoram	0.5:1
8	Strawberry	1.4:1
9	Cucumber	1:1
10	Lettuce	3.5:1

Optimal K:Ca – in terms of yields per plant – found for different plant species

You can see in the above results, that fairly high K:Ca ratios are typically required to increase yields. For most of the commercially grown flowering plants studied, it seems that a ratio of 1.5-2.0:1 will maximize yields without generating substantial problems in terms of Ca uptake. As mentioned above, higher K:Ca often push yields further, but with the presence of some Ca transport issues. A notable exception might be cucumber, for which the publication I cited achieved the maximum yield at a ratio of 1:1. However, good results were still achieved for 1.5:1.

Another important point about the ratio is that it is not independent of absolute concentration. As we saw in the previous section, the nature of the competition between K and Ca can change substantially depending on the absolute ion concentrations, so the above ratios must be taken within the context of their absolute concentration. The above ratios are generally given for relatively high EC solutions (1.5-3mS/cm).

Conclusion

The K:Ca ratio is a key property of hydroponic nutrient solutions. While the optimal ratio for a given plant species cannot be known *apriori*, it is reasonable to assume that the optimal ratio will be between 1:1 and 1:2 for most large fruiting crops and flowering plants that are popularly grown in soilless culture. This is especially the case if the hydroponic solution does not have a low EC. An optimal value below 1:1 is unlikely for most plants, although exceptions do exist in certain plant families that have peculiar Ca metabolisms.

To obtain the largest benefit, it would be advisable to run trials to optimize the K:Ca ratio for your particular crop, by changing the K:Ca ratio between 1:1, 1.5:1, and 2:1. You will likely see important differences when you carry out these trials, which will be useful to determine the highest yielding configuration for your setup. To perform these variations, it is usually easiest to change the ratio of potassium to calcium nitrate used in the nutrient solution.

Have you tried different K:Ca ratios? What do you grow and what has worked for you? Share with us in the comments below!

How to use organic fertilizers in Kratky hydroponics

I’ve written several posts in this blog about Kratky hydroponics (for example here and here). In this method, you use a bucket, a net pot, a small amount of media, and some nutrient solution, to grow a plant from start to finish. It requires no power or interventions in the case of leafy greens or small flowering plants. However, one of the requirements of a traditional Kratky setup is the use of regular hydroponic nutrients that are created from synthetic inputs. In this post, we are going to talk about the use of organic fertilizers in Kratky hydroponics, which inputs might work, and which will be problematic.

Plant grown in a traditional Kratky setup using synthetic fertilizers

The types of organic inputs

When people talk about “organic fertilizers”, they usually refer to inputs that can be used in the growing of organically certifiable foods. The easiest way to fit this definition is to look at the inputs that are listed by organizations like OMRI. However, among OMRI-listed products, we have significant differences in where the products come from, and this makes a huge difference in whether or not we could use them in a Kratky setup.

For the purposes of this post, we can divide the OMRI-listed products into three categories. We have mined materials, which are extracted and used in their raw form from the earth. We also have animal or vegetable sourced products, which are byproducts of some animal or vegetable industry, and we have processed products, which involve some postprocessing or mixing of products in the former categories.

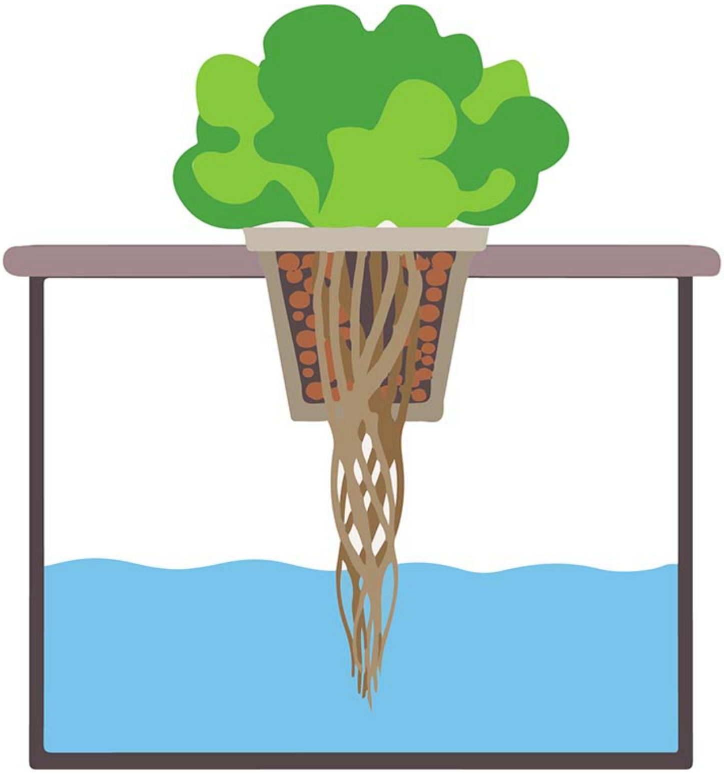
In the first category of products, we have things like mined magnesium sulfate, potassium sulfate, rock phosphate, sodium nitrate, or limestone. In the second category, we have things like fish emulsion, kelp extract, blood meal, and bone meal, while in the third category we have products like the Biomin series of transition metal chelates or any liquid or solid organic fertilizer blended products.

Why origin matters

The type of organic input matters, because Kratky hydroponic systems lack one important element. Oxygenation.

Since oxygen is not going to be injected into the nutrient solution, any input we use that requires oxygen for decomposition or absorption, or that requires oxygen for its proper uptake, is not going to work well. If you add any animal or vegetable product to a Kratky setup, the lack of oxygen in the solution is going to give way to the growth of anaerobic organisms that are going to be detrimental to plant growth and will lead to root rot.

Things like blood meal – which would be great amendments in soil with good aeration where oxygen can do its job – turn into foul mixes when put into a Kratky setup. This is because a Kratky setup has a stagnant body of water that is going to turn into a very unfavorable medium for plants as soon as we add anything that creates a heavily reducing environment.



A traditional Kratky setup. Note that the solution at the bottom is stagnant and not actively oxygenated in anyway. Only the oxygen that diffuses from the air gets into the water. This is enough to keep the submerged roots alive, provided that the solution itself does not act as a sink for oxygen. In these cases, root rot is quickly experienced.

Plant roots can tolerate a relatively oxygen-deprived solution to some extent, provided that enough root mass is above the water to take in oxygen, but they cannot tolerate a solution that is rid of all oxygen by anaerobic microbial activity. This is because oxygen deprivation makes the plant more vulnerable to attack by pathogens and hinders the respiration of plant roots, which is needed for root survival.

Which inputs can you use

In general, any input that heavily removes oxygen cannot be used as-is. This means that anything that contains plant or animal proteins, fats or carbohydrates, is not going to work well. Inputs that are heavily rich in bacteria or fungi, even beneficial ones, are also going to fail. This is because these beneficial microorganisms also require oxygen and, when they are put in a Kratky solution and die, they are digested by anaerobic organisms that can take their place.

Animal or vegetable inputs that are relatively inert in origin, such as bone meal, would not be problematic, but their ability to release nutrients is going to be limited in a Kratky solution. Mined inputs are going to be mostly fine. Soluble ones, like mined magnesium sulfate and potassium sulfate, are ideal replacements, as they are chemically identical to the synthetic ones, except for a higher content of impurities due to their raw origin. However, it will be difficult to provide enough nitrogen in an organic Kratky hydroponic setup using only this type of inputs.

A potential solution

Since the problem is mainly oxygen deprivation, we can use an organic hydroponic solution, as long as it is processed for long enough to completely eliminate the oxygen depriving capacity of the inputs. As an example, you can follow my instructions on preparing an organic hydroponic solution. This requires fermenting of the solution for a significant period of time, in order to ensure most of the oxygen requiring reactions have been carried out.

To use this solution in a Kratky setup, we would need to give it a longer period of time. We can verify that the solution is ready for Kratky by using an ORP meter and checking that the solution is at an ORP above 300mV after removing active oxygenation for a day. This means that the solution is able to keep enough dissolved oxygen and that most of the oxygen-hungry processes in the solution are done. This might take substantially longer than the 12-15 days suggested in my original article, probably around 30 days.

Another important step is the removal of bacteria and fungi, which could be very problematic once the solution reaches the stagnant conditions of the Kratky setup. To do this, the easiest solution would be to run the solution through a UV filtering system, in order to make sure all fungi and bacteria are removed from the solution. This might sound counterintuitive, but the Kratky system conditions are not ideal growing conditions for plants and do require us to minimize oxygen sinks in the system.

Conclusion

You can run a Kratky system using an organically derived fertilizer. However, it is not straightforward, as we need to consider that a Kratky system lacks the oxygenation required to carry out a lot of the processes that are taken for granted in organic growing (such as protein decomposition). Without aeration of the solution, we need to provide an organic solution that has already exhausted its hunger for oxygen and can already provide nutrients in a manner that is available to plants. We also need to ensure we add no fungi or bacteria that can work anaerobically and attack roots in the stagnant Kratky solution conditions. We can use tools like long-term fermentation with aeration, ORP meters, and UV systems to achieve this goal.

Have you ever grown in a Kratky setup using organic fertilizers? Let us know about your experience in the comments below!

The importance of accuracy in hydroponic nutrient preparation

When you prepare your own concentrated hydroponic nutrients, you need to carry out a significant number of measurements. As a consequence, you will deviate from your intended preparation by the errors inherent to these operations. Plants tolerate a significant array of conditions, so these errors – even though sometimes quite big – are often not big enough to kill plants and are therefore ignored by growers. These errors will, however, greatly hinder your ability to optimize and evolve your crop nutrition to a higher standard. In this post, we will talk about these errors, why and how they happen, when they are important, and how you can minimize them in order to obtain more reproducible results.

The markings in buckets can carry high systematic and random errors.

Types of error

Systematic Error

There are two types of errors that happen when anything is measured. The first is systematic error, which is the error inherent to calibration problems of the instrument. For example, you might be using a 1 gallon jug to prepare concentrated nutrients and always filling the jug to a mark you made on it. This mark is not going to be 1 gallon, but probably significantly over or under it. As long as you always use the same jug and fill to the same mark, this large deviation from 1 gallon will always be the same. As long as the measuring instrument is unchanged – meaning not recalibrated – the systematic error always remains the same in sign and magnitude.

Random Error

The second type of error relates to the randomness of the measuring process. Imagine that you used a sharpie to make the mark on the above-mentioned one-gallon jug, and you always try to measure to the same mark. The mark has some width, sometimes you will fill your jug up to the bottom of the mark, sometimes up to the top. Sometimes the surface where you place the jug where you measure will not be perfectly leveled, so the mark will be off because it will be higher at one side of the jug vs the other, etc. This error changes randomly, every time you measure. One time you might be +1%, the other -4%, etc.

Where the biggest errors happen

When you make your own hydroponic nutrients, you will be measuring two things: volume and mass. These two measurements will both carry systematic and random errors. The errors in scales are more obvious, so growers will always make an effort to get scales that are accurate enough for the measurements they want to make. For small growers, this means getting scales that can measure +/-0.01g with a decent capacity, normally 500g is fine. Buying weights to properly calibrate these scales is also recommended, in order to reduce systematic errors as much as possible.

However, always make sure you read at least 3 significant digits when making a weight measurement. This means if you need to measure 1.673485g, you need a scale that measures at least 2 digits, so that you can measure 1.67 +/- 0.01g. This will keep your error below the 1% mark. This is why it is often common to also get a +/-0.001g scale, to measure things like sodium molybdate. You can also go around this problem by preparing more concentrated solution, as your weights become larger, with larger volumes.

Volumes however are where the largest errors are accrued. Most growers will use non-calibrated receptacles to measure volume. The fact that something has a line drawn on it with a volume marking, does not mean that this line is accurate. The systematic errors in these receptacles are usually very large because these were never intended for accurate measurements of volume. **Things like buckets, beakers, tanks, and jugs, should not be used to measure volumes**. Wide containers, like buckets and tanks, also enhance errors that relate to parallax – your ability to judge whether a level of water is at a line – so the random component of your error will be quite large.

Consequences in nutrient values

In the best cases – for jugs, buckets, and tanks – the systematic error is around 10% with a random error of +/- 5% (3 sigma). If you are preparing a concentrated solution where the final expected concentration after dilution is 200 ppm of K, then this means that your actual K value in solution will start by being 10% over or under it – depending on which way the systematic error of your volume measurement goes – and then deviate +/-5% from there. This means that you are expected to get values all the way from 170 to 230 ppm in the final solution.

This is fine as far as keeping plants alive goes. A solution with 170 ppm will keep plants alive as well as a 230ppm solution would. This is the reason why most growers don't see an immediate need to reduce these errors. If you're growing healthy plants and you have less or more than what you intended, what is the problem?

How inaccuracy affects your process

There are three ways in which having inaccurately prepared solutions can affect your process. The first is that it makes you very vulnerable to changes. The second is that it makes it difficult for you to effectively optimize your setup, and the third is that it prevents others from being able to reproduce your results.

Changes in your setup can affect you deeply

Let’s say you optimized your nutrients with time and found that the optimal is 200ppm of K. In reality you have a bucket that always measures 10% less volume and you randomly deviate +/- 5% from that as well. This means that your final solutions are majorly in the 210-230 ppm range. Your trusty plastic bucket then cracks and you need to go and buy another one, you suddenly find that you’re not getting the same results. Now you have a bucket that just by chance, happens to measure the volume more accurately. You are now feeding 190-210ppm, substantially less K. You never knew that, you’re confused, you’re preparing everything the same way.

Your ability to optimize is hindered

The second problem is similar. Let’s say you prepared a batch of concentrated solution to compare feeding K at 180 ppm and K at 200 ppm. You prepare a single-stock solution to carry out the test. This bucket has a systematic error of +10% and a random error of +/-5%. For this batch, the solution happens to be 6% more concentrated than intended (+10% systematic, -4% random), so you end up with 190.8ppm and 212ppm. You find out that the 200 ppm preparation works better, so you decide to use it.

However, you run out of the stock solution you prepared for the experiment, so you prepare it again. However, you incur a different random error in this preparation – remember random errors are different every time you measure – and you end up being with a +1% random error, so a +11% total error. Your results are not as good as before, you don't know why. The reason, you're feeding 222ppm while in your previous experiment you had fed 212ppm. All while thinking you were feeding 200 ppm.

It becomes hard to share

Systematic and random errors can make effective sharing of results impractical. Imagine you have optimized your setup to the point where you're sure that the solution you prepare is the best one for a given plant under some given conditions. Then, you want to share this with another grower and tell him how to mix your formulation. This person tries it and tells you that your solution doesn't actually work the way you think. You might both be aiming for the same targets but hitting completely different numbers in reality. When sharing, it is important to share the numbers you aim for, as well as the error related to these values.

How to reduce errors

Prepare highly accurate small scale solutions

The easiest way to reduce errors when preparing hydroponic solutions is to base all preparations on small-scale experiments where the preparation can be done much more accurately, using calibrated volumetric material. Watch my videos on preparing hydroponic solutions, how to correctly prepare dilutions and how to characterize stock solutions, to learn more about how this is done.

Volumetric flasks can be used for highly accurate small scale preparations

The idea is that these small-scale preparations can tell you things such as: the amount of water you need to add for a given volume of stock solution, the expected conductivity of dilutions, and the expected density of the stock solution. Remember that salts take up volume, so to prepare 1 gallon of a concentrated stock solution you will need much less than 1 gallon of water. With this information, you can then prepare larger amounts of stock solutions, since you know the exact amount of water to add for a final volume, which you can accurately measure with a flow meter instead of having to use markings of any kind. You can then use the density measurement to check the accuracy of the preparation.

Perform fewer measurements

Every measurement you make incurs an additional error. It is better to prepare 2 concentrated nutrient solutions than to have 10 solutions with the salts being separated because you need to make 8 fewer volume measurements. If you minimize the number of measurements that you need to do to arrive at the nutrient solution that is fed to plants, you will also minimize the error incurred in these measurements. Minimize measurements from instruments with high errors. If your volumes have much more inaccuracy than your weights, prioritize lowering the number of times you measure volume vs weights.

Conclusion

Accuracy is something to strive for. It closes no doors, only opens them. It is not about being overly fuzzy or obsessive about it, it’s about using it to help you get better. Better practices, lower errors, more reproducibility, more learning. It’s a virtuous cycle. Errors are always there, whether you’re aware of them or not. Ignore them at your own peril.

If you have a process that is inaccurate that generates significant variations in your nutrient solution makeup, then these will be a problem, one way or another. You might be unable to judge whether changes in your crop are due to errors or due to changes, you might be unable to reproduce results and you might find yourself unable to meaningfully share results and explore with others. High accuracy is often not substantially expensive in hydroponics – instruments for accurate small-scale preparation are generally below the 200 USD mark total – and they can dramatically enhance the quality of your solutions and the conclusions you can make from experiments.

Do you prepare your own nutrient solutions? Do you know what your systematic and random errors are? Share with us in the comments below!