

Comparing Nutrient Solutions for Hydroponic Strawberry Production

Getting the right nutrient solution for strawberries in hydroponics can feel like trying to solve a puzzle where every piece matters. Unlike many crops where you can get away with a generic formula, strawberries are particularly responsive to nutrient composition, especially when it comes to the balance between nitrogen and potassium. Today, we will explore how different nutrient formulations affect both yield and fruit quality in soilless strawberry production.



A hydroponic strawberry production greenhouse

The Modified Steiner Approach

When researchers at the Technological Institute of Torreón tested different nitrogen and potassium combinations in strawberries, they discovered something important about how

these two nutrients interact. Using a [\(1\)](#) modified version of Steiner’s Universal Nutrient Solution, they evaluated twelve different formulations with nitrogen ranging from 126 to 210 ppm and potassium from 195 to 430 ppm.

The results were revealing. Plants receiving 168 ppm nitrogen combined with 430 ppm potassium achieved yields of 114 grams per plant, which was significantly higher than lower nitrogen treatments. However, here is where it gets interesting: while high nitrogen boosted yield, it actually decreased fruit quality. The highest soluble solids content (10.5 degrees Brix) occurred at the lowest nitrogen level of 126 ppm. This creates a real dilemma for growers who want both high yields and premium quality fruit.

Solution Type	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Yield	Quality Impact
Modified Steiner (Low N)	126	46	195	449	121	89.3 g/plant	Highest Brix (10.5°)
Modified Steiner (Medium N)	168	32	273	360	97	108 g/plant	Moderate Brix (10.0°)
Modified Steiner (High N)	210	19	194	413	111	111 g/plant	Lowest Brix (9.5°)

The Critical Role of Potassium

What emerged from this study was potassium’s profound impact on fruit quality. When potassium was increased to 430 ppm, the soluble solids climbed to 10.6 degrees Brix, and phenolic compounds reached their peak as well. The [\(1\)](#) research showed that the optimal combination for maximizing both yield and nutraceutical quality was 168 ppm nitrogen with 430 ppm

potassium, resulting in antioxidant capacity of 6305 microequivalents of Trolox per 100 grams.

This makes physiological sense. Potassium plays a fundamental role in sugar transport through the phloem, and when potassium availability is adequate, more sugars accumulate in the fruit. Meanwhile, excessive nitrogen tends to promote vegetative growth and the synthesis of nitrogen containing compounds like proteins and amino acids, rather than the accumulation of secondary metabolites that contribute to fruit quality.

Optimizing NPK Ratios for Chinese Greenhouses

A comprehensive study from China Agricultural University took a different approach by examining the combined effects of nitrogen, phosphorus, potassium, and water on strawberry production. Using a [\(2\)](#) quadratic regression design with 36 treatments, researchers determined that nitrogen was by far the most important factor, followed by water, then phosphorus, with potassium having the least impact on the sweetness to acidity ratio.

Their optimal formulation for achieving yields above 110 grams per plant with excellent fruit quality included nitrogen at 156 to 172 ppm (supplied as calcium nitrate), phosphorus at 54 to 63 ppm (as sodium dihydrogen phosphate), and potassium at 484 to 543 ppm (from potassium sulfate). This represents significantly higher potassium levels than the Steiner based formulations, suggesting that when other nutrients are optimally balanced, strawberries can benefit from even more potassium.

Nutrient	Optimal Range (ppm)	Impact on Yield	Impact on Quality (SSC/TA)
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Nitrogen (N)	156 to 172	Most significant positive effect	Most significant factor
Phosphorus (P)	54 to 63	Moderate positive effect	Second most important
Potassium (K)	484 to 543	Significant positive effect	Minimal impact
Water	12.0 to 13.1 L/plant	Second most important	Third most important

The Calcium and Electrical Conductivity Question

While much attention focuses on NPK ratios, calcium concentration matters enormously in strawberry production. In the modified Steiner solutions, calcium ranged from [\(1\)](#) 244 to 449 ppm depending on the treatment. Higher calcium levels corresponded with lower nitrogen and potassium concentrations, maintaining appropriate osmotic potential.

Research has shown that the electrical conductivity (EC) of the nutrient solution significantly impacts strawberry performance in soilless culture. Studies using different EC levels found that [\(3\)](#) 1.3 mS/cm was optimal for spring production, while 2.2 mS/cm proved better during winter months. This seasonal adjustment reflects the plant's changing water use and nutrient demand patterns throughout the growing cycle.

Micronutrient Considerations

While macronutrients get most of the attention, micronutrient composition matters too. The [\(1\)](#) modified Steiner formulations included iron at 5 ppm, manganese at 1.6 ppm, boron at 0.865 ppm, zinc at 0.023 ppm, copper at 0.11 ppm, and molybdenum at

0.048 ppm. These concentrations remained constant across all treatments, suggesting that within reasonable limits, macronutrient balance has a more pronounced effect on yield and quality than micronutrient variation.

Making Practical Choices

So what should you actually do with this information? If you are growing strawberries hydroponically and want to maximize both yield and quality, consider starting with a solution containing approximately 160 to 170 ppm nitrogen, 55 to 60 ppm phosphorus, and 400 to 500 ppm potassium. Maintain the K:Ca ratio near 1-1.4:1 and the K:Mg ratio near 4:1. This matches some of [my previous publications](#) on the K:Ca ratio.

Remember that these recommendations assume you are maintaining appropriate pH (around 5.5 to 6.0) and EC levels suitable for your growing conditions. The [\(2\)](#) research demonstrated that excessive nutrients actually decreased both yield and quality, so more is definitely not better. You will need to adjust based on your specific cultivar, climate, and growing system, but these ranges provide a solid starting point backed by peer reviewed research.

The key takeaway is that strawberry nutrition in hydroponics requires a delicate balance. While nitrogen drives yield, potassium enhances quality, and the interaction between these two nutrients determines your ultimate success. Monitor your plants carefully, conduct tissue analysis when possible, and do not be afraid to adjust your formulation based on what the plants are telling 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 Auxege 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 'Pirquin', 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 [\(5\)](#).