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

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

A soilless cucumber greenhouse using coco coir.

Substrate choices: coir, waste materials and microbiome effects

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

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

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

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

Takeaway: Coir is a proven upgrade over rockwool. Waste-based

and fiber blends can substitute part of peat if their hydrophysical traits are tuned. Substrates also rewire root microbiomes, adding another layer to consider.

Irrigation and fertigation: oxygenation and nutrient recipes

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

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

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

Nutrient interactions: silicon and iron

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

Biostimulants and stress management

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

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

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

Takeaway: Humic acids and grafting can buffer salinity stress,

while microalgae show root growth potential. None of these replace proper fertigation, but they add resilience once fundamentals are stable.

Practical synthesis

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