Cobalt in hydroponics as a biostimulant

People ask about dosing cobalt in recirculating systems to "stimulate" growth or flowering. For the crops that matter in hydroponics and soilless culture, peer-reviewed work does not show reliable growth or yield benefits from adding cobalt to the solution. What the literature *does* show is straightforward: cobalt is readily taken up at low ppm, it inhibits ethylene biosynthesis at pharmacological doses, and it becomes toxic fast when you push concentration. The burden of proof for agronomic benefit is still unmet. Below I summarize what high-quality studies in hydroponics and soilless systems actually report.

cobalt (II) chloride, the most common form of chloride used in studies

What cobalt does in plants

Cobalt is not established as essential for most higher plants. It is essential for N-fixing microbes and therefore matters in legumes, but for tomato, cucumber, lettuce and the like, its status is “potentially beneficial at very low levels, toxic at modest excess.” A recent review frames this clearly and compiles transport and toxicity data across species (Frontiers in Plant Science, 2021).

A second, practical point is mechanism. Cobalt ions inhibit ACC oxidase, the last step in ethylene biosynthesis. That is why physiologists use cobalt chloride in short, high-dose treatments to suppress ethylene responses in experimental tissues. Classic work documents this inhibition in cucumber and other plants (Plant Physiology, 1976).

Ethylene inhibition can, in principle, delay senescence or alter stress signaling. The catch is dose. The amounts that clearly block ethylene in lab tissues are usually far above what you want sloshing around a long-cycle greenhouse system, and benefits rarely translate to whole plants under production conditions.

What happens in hydroponics and soilless systems

Tomato

Nutrient solution exposure, subtoxic range
Tomato grown hydroponically with cobalt at **0.30 ppm** and **1.18 ppm** showed strong root retention and limited shoot transfer. This is uptake behavior, not a biostimulant response, and the authors did not report yield benefits. The forms used were cobalt(II) salts in solution culture (Environmental Science & Technology, 2010).

Toxicity under higher exposure
A hydroponic study imposed severe cobalt stress at **23.57 ppm** and observed depressed biomass, disrupted water status, chlorophyll loss and oxidative damage in tomato. Cobalt was supplied as cobalt chloride in the nutrient media. Plant growth regulators mitigated symptoms but did not make cobalt itself beneficial (Chemosphere, 2021).

Lettuce

Toxicity in greenhouse hydroponics with inert media
Iceberg lettuce grown in a perlite based hydroponic system suffered growth and pigment losses at **11.79 ppm** cobalt. Cobalt was added as cobalt salt to a modified Hoagland solution. The same paper showed nitric oxide donor treatments could blunt the damage, which again argues cobalt at this level is a stressor, not a stimulant (Chilean Journal of Agricultural Research, 2020)

Cucumber

Mechanistic ethylene work, not production benefit
Multiple peer-reviewed studies in cucumber use cobalt chloride as an ethylene biosynthesis inhibitor in explants or short assays. These demonstrate the mechanism but are not agronomic validations for dosing cobalt into a recirculating system for weeks (Plant Physiology, 1976; Forests, 2021).

Summary table of relevant studies in hydroponics and soilless culture

Crop	System	Cobalt form	Solution cobalt (ppm)	Exposure description	Main outcome
Tomato	Aerated nutrient solution	Co(II) in solution culture	0.30 and 1.18	Whole plants in controlled hydroponics	Strong root retention, limited shoot transport; no biostimulant effect reported. ES&T 2010 PubMed

Crop	System	Cobalt form	Solution cobalt (ppm)	Exposure description	Main outcome
Tomato	Hydroponic solution, stress test	Cobalt chloride	23.57	Whole plants, growth regulators tested for mitigation	Marked toxicity: biomass and chlorophyll decreased, oxidative stress increased. Chemosphere 2021
Lettuce	Perlite + recirculating solution	Cobalt salt in modified Hoagland	11.79	Greenhouse hydroponics with inert media	Significant growth and pigment losses at this dose; NO donor partially mitigated damage. Chilean J. Agric. Res. 2020
Cucumber	Short mechanistic assays	Cobalt chloride	used as ethylene inhibitor in short assays	Explants or detached tissues	Confirms ethylene inhibition by Co^{2+}; not a production recommendation. Plant Physiology 1976

So is cobalt a biostimulant in hydroponic vegetables

For tomato, cucumber and lettuce grown hydroponically or in soilless culture, peer-reviewed journal data do not support cobalt as a legitimate biostimulant input. You can inhibit ethylene transiently with cobalt chloride in lab tissues, but that is not a recipe for higher yield in a recirculating system. The agronomic studies that actually dose solutions show either neutral responses at sub-ppm levels or clear toxicity when you push into low double digits. The general biology context from a recent cobalt review matches this picture and does not contradict it (Frontiers in Plant Science, 2021).

Practical guidance for hydroponic and soilless growers

Default practice
Do not add cobalt intentionally to non-legume hydroponic recipes. There is no reproducible benefit and real risk of toxicity in the low tens of ppm, with lettuce showing damage already at **~12 ppm** and tomato at **~24 ppm** under hydroponic conditions. (see here, or here)

If you want to experiment
Keep total cobalt in solution at **sub-ppm** levels and treat it as a research trial, not a production strategy. Track solution cobalt with ICP if you can. The only peer-reviewed hydroponic tomato data near this range are **0.30 to 1.18 ppm**, which documented transport behavior, not stimulation.

Forms used in the literature
Cobalt chloride is the dominant form when researchers test ethylene inhibition or impose cobalt stress. Cobalt sulfate also appears in some soilless protocols. Neither form has peer-reviewed evidence of yield stimulation in hydroponic tomato, cucumber or lettuce. (see here or here)

Legumes are the exception
Cobalt matters indirectly via N-fixing symbionts. If you are growing legumes in soilless systems, cobalt management belongs in the microbial nutrition discussion, not as a general biostimulant for non-legumes (see here).

Crop	"Stimulant" claim in journals	Reported beneficial window	Toxicity begins around	Notes
Tomato	None in hydroponic journals	None demonstrated	~23.6 ppm in nutrient solution	Sub-ppm exposures documented uptake with no benefit. ES&T 2010; Chemosphere 2021
Lettuce	None in hydroponic journals	None demonstrated	~11.8 ppm in nutrient solution	Damage includes biomass and chlorophyll loss in greenhouse hydroponics. Chilean J. Agric. Res. 2020
Cucumber	Mechanistic ethylene inhibition only	Not applicable	Not defined for production, lab tissues often use high short-term doses	$CoCl_2$ used to block ethylene in explants; not a production recommendation. Plant Physiology 1976

Bottom line

If you grow tomato, cucumber or lettuce in hydroponics or inert media, cobalt is not a proven biostimulant. At sub-ppm levels you might see nothing. Push it into the low tens of ppm and you will see toxicity. The only unequivocal "effect" you can count on is ethylene inhibition during short, high-dose laboratory treatments with cobalt chloride, which is not a safe or sensible production tactic. Until robust, peer-reviewed hydroponic trials show yield or quality gains at practical ppm, the rational move is to leave cobalt out.

The use of phosphites in plant culture

Plants normally get most or all of their phosphorous from inorganic phosphorus sources. Most commonly these sources are monobasic or dibasic phosphate ions ($H_2PO_4^-$ and HPO_4^{-2}), which are naturally formed from any other phosphate species at the pH values generally used in hydroponics (5.5-6.5). However these are not the only sources of inorganic phosphorous that exist. Phosphite ions – which come from phosphorous acid H_3PO_3 – can also be used in plant culture. Today we are going to talk about what phosphite does when used in hydroponics and why it behaves so differently when compared with regular phosphate sources. In research P from phosphate is generally called Pi, so I will follow this same convention through the rest of this post. A good review on this entire subject can be found here.

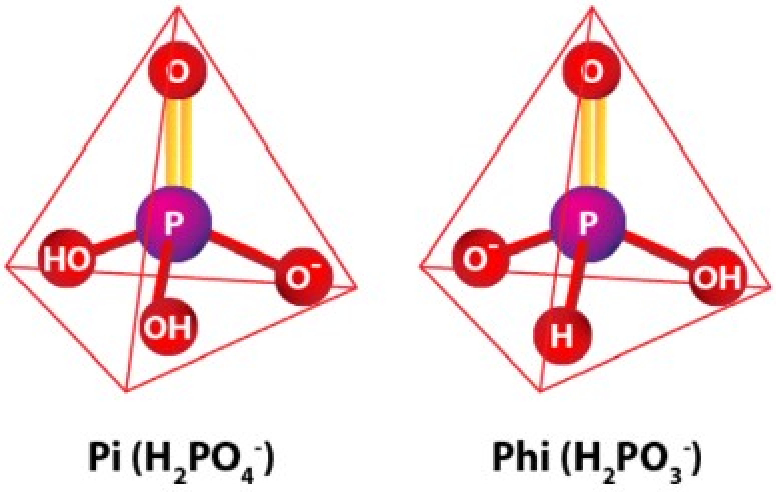

Fig. 1. Three-dimensional chemical structures of phosphate ($H_2PO_4^-$; Pi) and phosphite ($H_2PO_3^-$; Phi) forming tetrahedral structures.

The role that phosphite (Phi) plays in plant nutrition and development has now been well established. Initially several people claimed that Phi was a better P fertilizer than Pi so researchers wanted to look into this to see if Phi could actually be used as an improvement over Pi fertilization. However research was heavily disappointing, studies on lettuce (here) , spinach (here), komatsuna (here) as well as several other plants showed that Phi fertilization provides absolutely no value in terms of P nutrition, meaning that although plants do absorb and process the Phi it does not end up being used in plant tissue to supplement or cover P deficiency in any way. Furthermore there are some negative effects when Phi is used in larger concentrations (as those required for Pi) so it quickly became clear that Phi is not a good fertilizer at all.

Why should anyone use Phi then? Well, research started to show that some of the earlier positive results of Phi fertilization were not because it was covering Pi deficiencies but mainly because it was offering a protective effect against some pathogens. Research on tomatoes and peppers and other plants (here and here) showed that phosphites had some ability to protect plants against fungi with plants subjected to Phi applications showing less vulnerability to the pathogens. However the evidence about this is also not terribly strong and a few papers have contested these claims.

Table 1
Beneficial effects of phosphite (Phi) as a biostimulator in vegetable crops.

Crop	Phosphite source (dosage)	Method of application	Improved trait/s	Reference
Celery	Phosphorous acid	Foliar spray	Yield	Rickard (2000)
Lettuce	Phosphorous acid (50% of total P as Phi)	Nutrient solution in hydroponics	Biomass dry weight, foliar area and P content in the whole plant	Bertsch et al. (2009)
Onion	Phosphorous acid	Foliar spray and soil application	Percentage of jumbo size onions	Rickard (2000)
Potato	Phosphorous acid	Foliar spray	Size and yield of US No. 1 grade potatoes	Rickard (2000)
Potato	Potassium phosphite	Foliar application	Phytoalexin and chitinase content, and yield maintenance	Lobato et al. (2011)
Potato	Potassium phosphite	Sprays applied to seed tubers and foliage	Reinforcement of the cell wall and defense response	Olivieri et al. (2012)
Potato	Potassium phosphite	Liquid solution applied to tubers	Emergence, early growth and mycorrhizal colonization	Tambascio et al. (2014)
Potato	Potassium phosphite	Foliar spray	Chlorophyll content, protection against UV-B light and activation of the antioxidant system	Oyarburo et al. (2015)
Sweet pepper	Phosphorous acid	Drip irrigation and foliar spray	Size and yield of US No. 1 grade peppers	Rickard (2000)
Tomato	Phosphorous acid (50% of total P as Phi)	Nutrient solution in hydroponics	Biomass dry weight, foliar area and P content in the whole plant	Bertsch et al. (2009)

Note: Most studies were based on the application of commercial Phi-containing products without clear indication on the labels of their precise Phi content. Therefore, Phi dosage in the table is only indicated when precise data are available in the cited articles.

Table 2
Beneficial effects of phosphite (Phi) as a biostimulator in fruit crops.

Crop	Phosphite source (dosage)	Method of application	Improved trait/s	Reference
Avocado	Phosphorous acid	Foliar spray	Yield of commercially valuable sized fruit	Lovatt (2013)
Banana	Phosphorous acid (50% P as HPO_4^{2-} and 50% as $H_2PO_3^-$)	Nutrient solution in hydroponics	Biomass dry weight, foliar area and P content in the whole plant	Bertsch et al. (2009)
Citrus	Phosphorous acid	Foliar spray	Yield and acid content in fruits	Lovatt (1998, 1999)
Citrus	Phosphorous acid	Foliar spray	Yield	Albrigo (1999)
Citrus	Phosphorous acid	Foliar spray	Yield	Rickard (2000)
Peach	Phosphorous acid	Foliar spray	Sugar and soluble solids content	Rickard (2000)
Raspberry	Phosphorous acid	Foliar spray	Fruit firmness	Rickard (2000)
Strawberry	Potassium phosphite	Plants soaked and irrigated	Fruit acidity, ascorbic acid and anthocyanin content	Moor et al. (2009)
Strawberry	Potassium phosphite (6.7% of total P as Phi)	Root application through a controlled watering system	Growth of roots and shoots	Glinicki et al. (2010)
Strawberry	Phosphorous acid (30% of total P as Phi)	Nutrient solution applied to the roots	Concentrations of chlorophylls, amino acids and proteins in leaves	Estrada-Ortiz et al. (2011)
Strawberry	Phosphorous acid (20% of total P as Phi)	Nutrient solution applied to the roots	Sugar concentration and firmness of fruits	Estrada-Ortiz et al. (2012)
Strawberry	Phosphorous acid (20–30% of total P as Phi)	Nutrient solution applied to the roots	pH, EC and anthocyanin concentration in fruits	Estrada-Ortiz et al. (2013)

Note: Most studies were based on the application of commercial Phi-containing products without clear indication on the labels of their precise Phi content. Therefore, Phi dosage in the table is only indicated when precise data are available in the cited articles.

Those who say that Phi is not mainly a fungicide claim that positive results are mainly the effect of Phi acting as a biostimulant (here). These groups have shown through research across several different plant species, including potatoes, onions, lettuce, tomatoes, wheat, oilseed rape, sugar beet and ryegrass that foliar or sometimes root applications of phosphites consistently yield some positive effects, meaning that there is a strong biostimulant effect from the Phi that is not related to either P nutrition or a fungicidal effect. A recent review looking at the overall biostimulant effects of Phi (here) shows how researchers have obtained evidence of biostimulation in potatoes, sweet peppers, tomatoes and several other species (the images in this post were taken from this review). The different studies mentioned in the review show increases in quality and even yields across these different plant species (see tables above).

While we know that Phi is not a good source of P nutrition and we know it can help as a fungicide in some cases it is clear now that under enough Pi nutrition Phi can provide some important biostimulating effects. Negative effects from Phi seem to be eliminated when enough Pi nutrition is present so rather than be thought of as a way to replace or supplement P nutrition it should be thought of as an additive that has a biostimulating effect. Phi may become a powerful new tool in the search for higher yields and higher quality, while not serving as a replacement for traditional Pi fertilization.