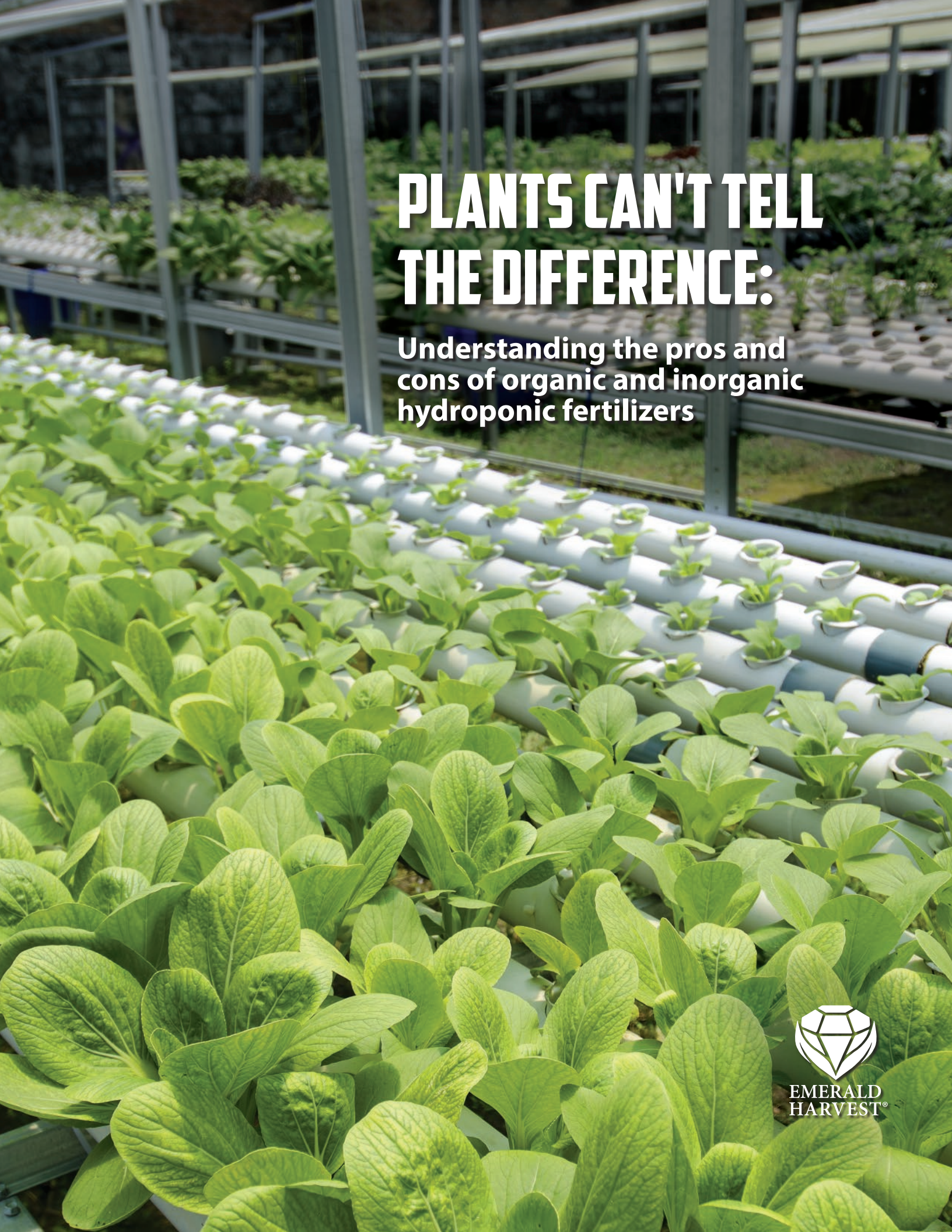


PLANTS CAN'T TELL THE DIFFERENCE:

Understanding the pros and cons of organic and inorganic hydroponic fertilizers

EMERALD HARVEST®

Inorganic fertilizers have a bad rep.

Often called "synthetic," "chemical" and "artificial," many believe inorganic fertilizers are full of dangerous ingredients that are harmful to humans and the environment.

This perception has driven many growers to choose organic fertilizers instead. Many view organic fertilizers as safer, cleaner and better for the environment. Some may believe that if the fertilizer is organic, they can label their plants organic too.

But the truth isn't so black and white.

There's no evidence that plants grown with inorganic fertilizers are unsafe for human consumption. While some inorganic fertilizers are synthetically produced, many are sourced from high-quality raw minerals naturally found in the earth. And the stories we hear about inorganic fertilizers damaging the environment are mostly traced back to traditional farming—a completely different production system from hydroponics.

Organic fertilizers certainly have their benefits, but those benefits can be harder to realize in hydroponic systems.

Neither organic nor inorganic fertilizers are inherently good or bad. There are pros and cons to each. Both have a place in hydroponics, and combining them can provide the best of both worlds.

That's what this white paper will address. First, we'll explain the scientific differences between the different types of fertilizers—and what those differences mean when it comes to regulations and the marketing of crops fertilized by them. Then we'll discuss the advantages and challenges of using each. Finally, we'll cover why growers don't need to choose one over the other but can incorporate both for successful hydroponic production.

DEFINING THE DIFFERENCES

Before we discuss the differences between the different types of fertilizers, let's first define fertilizer.

Fertilizer is any material that supplies one or more nutrients essential to plant growth. The material can be organic or inorganic and sourced from natural material or made synthetically.[1] It can contain one of the three primary macronutrients—nitrogen (N), phosphorus (P) and potassium (K)—as well as secondary macronutrients, micronutrients or combinations of the above. Fertilizers can be applied directly to the plant roots or to the leaves (via foliar spray), or they can be applied indirectly through soil irrigation.

So what's the difference between organic and inorganic fertilizers? In short, carbon (C). In addition to containing at least one mineral plant nutrient, organic fertilizers must contain carbon (as well as hydrogen and oxygen, which are also present in many inorganic fertilizer compounds).[2] This means they are usually derived from the byproducts or remains of an organism.

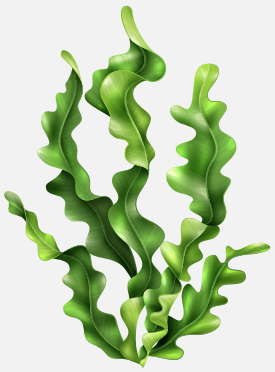
1 Kuntal Hati and Kalikinkar Bandyoopadhay, "Fertilizers (Mineral, Organic), Effect on Soil Physical Properties," Encyclopedia of Agrophysics, Encyclopedia of Earth Sciences Series (2011): https://doi.org/10.1007/978-90-481-3585-1_201

2 Ibid.

Examples of materials used to make organic and inorganic fertilizers

Organic fertilizers:

- Guano
- Worm castings
- Humic acid
- Kelp
- Alfalfa



Inorganic fertilizers:

- Mined rock (e.g., rock phosphate)
- Mined mineral salt (e.g., potash)
- Atmospheric nitrogen (used to create ammonia)
- Methane (used to create ammonia)
- Carbon dioxide (used to create urea)*

* The carbon is lost when urea is created, which is why it is not considered an organic fertilizer.

Inorganic fertilizers, on the other hand, don't have carbon as an essential component of their makeup. They can be mineral, synthetic or chemical, with each differing in the degree of processing they undergo.

Mineral fertilizers can be manufactured or sourced from natural materials, such as rock or mineral salts, which are processed for plant absorption. Aside from nitrogenous fertilizers, they are usually purified minerals.[3]

Phosphorus fertilizer is one example. The raw material, rock phosphate, is often used to manufacture it. But because the phosphorus availability in it is low, it's usually treated in an electric furnace or with acid and gypsum to create orthophosphoric acid, the phosphate form plants can absorb.[4] The potassium in the fertilizer goes through a similar process. Minerals with potassium are mined and purified with dry and slurry processes, resulting in potassium chloride. Potassium chloride can then be treated with sulfuric acid at a high temperature to create potassium sulfate.[5]

Synthetic fertilizers contain inorganic compounds usually derived from byproducts of the petroleum industry. For example, the fertilizer anhydrous ammonia is created by the Haber-Bosch process, where atmospheric nitrogen is combined with hydrogen at a high temperature and pressure. Steam reforming of natural gas can serve as the source of hydrogen for the process.[6]

Chemical fertilizers, on the other hand, are man-made fertilizers produced through chemical reactions. Urea can be considered a chemical fertilizer because it is developed from a process whereby ammonia and carbon dioxide react to create ammonium carbamate, which is then dehydrated to urea.[7]

It's important to remember that all fertilizers—both organic and inorganic—technically contain chemicals. The very nutrients plants need to survive and thrive are in fact chemical elements.

3 K. F. Isherwood, "Mineral Fertilizer Use and the Environment," International Fertilizer Industry Association (2000): 7, https://issuu.com/rareearthminerals/docs/ifa-unep

4 "Understanding phosphorus fertilizers" University of Minnesota Extension; accessed June 1, 2021, https://extension.umn.edu/phosphorus-and-potassium/understanding-phosphorus-fertilizers

5 "Potassium fertilizers – Manufacturing process of Potassium fertilizers" Guichon Valves; accessed June 1, 2021, https://guichon-valves.com/faqs/potassium-fertilizers-manufacturing-process-of-potassium-fertilizers/

6 Kazafy Sabry, "Synthetic Fertilizers; Role and Hazards," (2015): https://doi.org/10.13140/RG.2.1.2395.3366

7 "Urea Production and Manufacturing Process," Independent Commodity Intelligence Services (2010); accessed July 10, 2021, https://www.icis.com/explore/resources/news/2007/11/07/9076560/urea-production-and-manufacturing-process/

ORGANIC FERTILIZERS VERSUS ORGANIC LABELING

Now that we've covered the differences between organic and inorganic fertilizers, we need to clarify what it actually means to label a crop organic.

In the US, Canada, the European Union and many other countries, you can't label fruits and vegetables, packaged food or other goods "organic" unless they're certified through the governing body's organic program. In the US, certification falls under the National Organic Program (NOP) of the US Department of Agriculture (USDA).[8] It's illegal for any produce or goods to bear the USDA Organic Seal or use the word "organic" on its packaging without being reviewed and approved by a USDA-accredited certifying agent.[9]

To receive organic certification, growers must follow production methods approved by their country or state. In the US, one of those practices includes using only organic fertilizers.[10] While there are a few exceptions, most inorganic fertilizers cannot be used in organic production. Those permitted are listed in the National List of Allowed and Prohibited Substances, which can be accessed via the USDA website: https://www.ams.usda.gov/rules-regulations/national-list-allowed-and-prohibited-substances.

While organic growers can use raw forms of organic fertilizer, such as manure, they can also check the Organic Materials Review Institute (OMRI) for fertilizers approved for organic production.[11] California growers can also check the state's Organic Input Material (OIM) Program.[12] Products with the OMRI or OIM seals can be used on certified-organic acres and operations.

It must be stressed that even if a grower uses only organic fertilizers, they cannot sell their crops as organic without certification.

8 Some states may have their own State Organic Program, upon approval by the USDA National Organic Program, which allows them to oversee organic production and handling within the state.

9 "About Organic Labeling," Agricultural Marketing Service, US Department of Agriculture; accessed June 1, 2021 https://www.ams.usda.gov/rules-regulations/organic/labeling

10 Pamela Coleman, "Guide for Organic Crop Producers," National Center for Appropriate Technology, ATTRA Sustainable Agriculture (2012); accessed June 1, 2021, https://attra.ncat.org/product/guide-for-organic-crop-producers/

11 OMRI is a third-party nonprofit accredited to ISO 17065 standards by the USDA Quality Assessment Division to review inputs, including fertilizers, intended for use in certificated organic production.

12 OIM is run by the California Department of Food and Agriculture to register fertilizers used in organic crop and food production. OIM-labeled products comply with the California Fertilizing Materials Law and Regulations in addition to USDA NOP standards.

CAN CANNABIS BE ORGANIC?

In the US, under the current USDA NOP standards, cannabis cannot be certified organic because it is still considered a Schedule I drug, and its production is illegal under federal law. Only hemp and hemp-derived products such as CBD oil can be certified organic, since the 2018 Farm Bill permits hemp production.

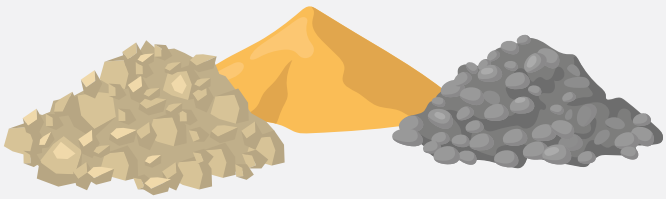
However, states where cannabis is legal may have or be developing their own organic certification standards specifically for the crop. As of 2021, California's Department of Food and Agriculture (CDFA) was in the process of creating a statewide certification program for cannabis that will be comparable to NOP standards.[13] Growers should check with their state's or country's agricultural department to learn if they can organically certify their cannabis in the state.

13 "OCal Program," California Department of Food and Agriculture (2021); accessed July 10, 2021; https://www.cdfa.ca.gov/calcannabis/ocal.html

Glossary of fertilizer terms

Organic fertilizer
A fertilizer that contains one or more essential plant nutrients along with carbon, hydrogen and oxygen. Its nutrients are derived from the remains or byproducts of an organism, such as animal waste or plant compost.

Inorganic fertilizer
A fertilizer that contains one or more essential plant nutrients, but carbon is not an essential component of its basic chemical structure. Materials can be of synthetic, mineral, chemical or artificial origin.



Mineral fertilizer
Fertilizer that is either manufactured or sourced from natural materials, such as rock or a mineral salt. Aside from nitrogenous fertilizers, they are typically made of purified minerals. They are not permitted under certified organic production because they are processed for plant absorption.*

Synthetic fertilizer
Fertilizer made of inorganic compounds, usually derived from byproducts of the petroleum industry.

Chemical fertilizer
Fertilizer that is produced industrially by humans through chemical reactions.

* As defined by the Electronic Code of Federal Regulations under the National Organic Program. See law.cornell.edu/cfr/text/7/205.2 for full definition.

In the meantime, the Cannabis Certification Council (CCC) has developed its own standards and certification criteria under its Organically Grown Cannabis Certification Program. The program has adopted USDA organic regulations where practicable. Cannabis growers can seek certification from organic certifying agencies that have been accredited by the CCC.[14] Additional certifications are available through other organizations, which you can learn about at whatsinmyweed.org.

14 "#WhatsInMyWeed; Clean Cannabis Certifications" Cannabis Certification Council; accessed June 1, 2021, https://www.cannabiscertificationcouncil.org/blog/whatsinmyweed-clean-cannabis-certifications

What does it really mean when a label says "organic"?

If you've shopped for organic products, you've probably noticed the labeling isn't consistent. Some products have the USDA Organic Seal, while others may just say "made with organic." So what's the difference? The USDA NOP has four labeling categories for organic products. Here's what they mean:

100% organic

One hundred percent of the ingredients are certified organic and the label may include the USDA Organic Seal on the primary display panel—the portion of the panel consumers are most likely to see.

Organic

The product and ingredients are certified organic and can use the USDA Organic Seal. However, non-organic ingredients permitted on the National List of Allowed and Prohibited Substances may be used in the product, provided they don't make up more than five percent of the combined total ingredients.

Made with organic

At least seventy percent of the product contains certified organic ingredients. The USDA Organic Seal can't be used and organic claims on the label must be specific: for example, "made with organic oats" instead of "made with organic ingredients." Up to three ingredients or ingredient categories can be represented as organic. Remaining ingredients don't need to be organic but must be non-GMO, and any non-ag products must be permitted by the National List of Allowed and Prohibited Substances, such as baking soda in baked goods.

Specific organic ingredients

Applies to products that have less than seventy percent certified organic ingredients. The product itself does not need to be certified and cannot use the USDA Organic Seal or the word organic on the primary display panel. Products in this category can only list the certified organic ingredients in the ingredients list and the percentage of organic ingredients.

PLANTS DON'T CARE ABOUT THE SOURCE OF NUTRIENTS

Despite the scientific and regulatory differences between organic and inorganic fertilizers, plants don't care where their nutrients come from. In fact, at the level of essential plant nutrients, they can't tell the difference between organic and inorganic fertilizers. That's because they're only capable of absorbing essential nutrients in certain forms. Figure 1 shows which chemical forms of each nutrient are commonly taken up by plants.

For example, plants can only absorb nitrogen as nitrate (NO_3^-) ions or ammonium (NH_4^+) ions—both of which are inorganic forms. When a plant is fertilized with manure or compost where nitrogen is still in its organic form, it's unavailable to the plant until it is converted into inorganic forms through a process called mineralization.[15]

15 "Crop Plants Take Up (Absorb) Nutrients in Inorganic Form," International Plant Nutrition Institute; accessed July 10, 2021, http://www.ipni.net/publication/envb.nsf/0/22E42BA77D7347E5852579E4006E886E/$FILE/09062-01-Enviro-Brief-01.pdf

Figure 1. Chemical forms of nutrients that plants absorb

Nutrient	Chemical forms commonly taken up by plants
Nitrogen (N)	NO_3^-, NH_4^+
Phosphorus (P)	$H_2PO_4^-$, HPO_4^{2-}
Potassium (K)	K^+
Calcium (Ca)	Ca^{2+}
Magnesium (Mg)	Mg^{2+}
Sulfur (S)	SO_4^{2-}
Boron (B)	BO_3^{3-}
Chloride (Cl)	Cl^-
Copper (Cu)	Cu^{2+}
Iron (Fe)	Fe^{2+}
Manganese (Mn)	Mn^{2+}
Molybdenum (Mo)	MoO_4^{2-}
Zinc (Zn)	Zn^{2+}
Nickel (Ni)	Ni^{2+}

* Table data source: Natalie Bumgarner and Robert Hochmuth, "An Introduction to Small-Scale Soilless and Hydroponic Vegetable Production," University of Tennessee Institute of Agriculture, https://extension.tennessee.edu/publications/Documents/W844-A.pdf

MICROBES NECESSARY FOR ORGANIC FERTILIZATION

For mineralization to occur, microorganisms need to be present. Beneficial microbes are responsible for breaking down the organic forms of essential nutrients into their inorganic, plant-usable forms.

In traditional farming and production systems where plants grow in soil, those microorganisms are already present. But hydroponic systems don't have enough microbes to mineralize nutrients into inorganic forms. Unless the organic fertilizer is already water-soluble and microbially pre-processed before it's incorporated with the hydroponic solution, growers will need to apply a root inoculant to establish microbial colonies.[16]

Inorganic fertilizers bypass the mineralization process because their nutrients are already in plant-usable forms. Most of these fertilizers are water-soluble, and plants can absorb their nutrients immediately.

ORGANIC FERTILIZERS PAY OFF IN SOIL

Because organic fertilizers require microbes to convert their nutrients into plant-absorbable forms, most of the benefits associated with organic fertilizers apply to soil-based growing systems.

One of the biggest benefits of applying organic fertilizers to soil is that they contribute to soil health. There's evidence that applying manure with high carbon content increases soil organic matter, enriching the soil with nutrients. Adding organic matter like manure also helps reduce soil compaction, improve soil aggregation, and increase the soil's water infiltration and water-holding capacities.[17]

The contribution of organic matter also tends to give the soil pH a higher buffering capacity.[18] The pH impacts nutrient availability, so if it's not in the optimal range, plants may not get the nutrients they need (see Figure 2).

16 Makoto Shinohara, Chihiro Aoyama, Kazuki Fujiwara, Atsunori Watanabe, Hiromi Ohmori, Yoichi Uehara and Masao Takano, "Microbial mineralization of organic nitrogen into nitrate to allow the use of organic fertilizer in hydroponics," Soil Science and Plant Nutrition, 57:2 (2011), 190-203, https://doi.org/10.1080/00380768.2011.554223

17 Agustin Olivo, "How can animal manure help my soils be healthier and more productive?" University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, UNL Water; accessed June 1, 2021, https://water.unl.edu/article/manure-nutrient-management/how-can-animal-manure-help-my-soils-be-healthier-and-more

18 "Soil pH" Soil Health – Guides for Educators, USDA NRCS 2014, https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051574.pdf

Another benefit is the fact that the nutrients in organic fertilizers are not immediately available to plants. The slow release of essential nutrients from mineralization means the plants can be fertilized throughout different growth stages. It also helps prevent salt damage to crops and reduces the odds of losing nutrients to the environment through leaching, erosion, denitrification and volatilization.[19]

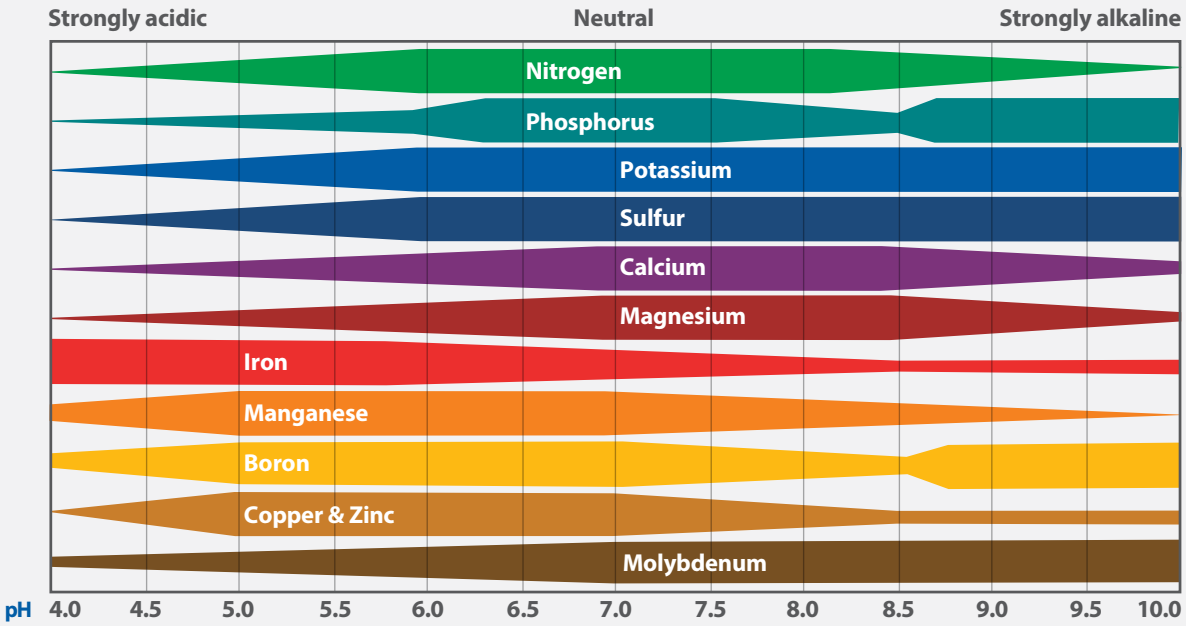
But these benefits don't transfer to hydroponic systems.

Without soil, plants might not get the microbial benefits of using organic fertilizers. In soil, organic fertilizers support a thriving microbial community that helps prevent disease, as beneficial microorganisms outcompete pathogens for resources.[20] But hydroponic growers need to use microbial inoculants to reap those benefits. The inoculants can colonize the rhizosphere even in soilless conditions, but they won't appear on their own; they have to be applied.

19 George Silva, "What organic fertilizers mean to plants and soil," Michigan State University Extension; accessed June 1, 2021, https://www.canr.msu.edu/news/what_organic_fertilizers_mean_to_plants_and_soil

20 Kimberly Williams and J.S. Nelson, "Challenges of using organic fertilizers in hydroponic production systems," Acta Horticulturae, 1112 (2016): 365-370, https://doi.org/10.17660/ActaHortic.2016.1112.49

Figure 2. Nutrient availability based on pH range



Inoculants aren't the only supplement hydroponic growers need to apply. The organic matter that is so beneficial to soil tends to cause problems in hydroponics. Growers have reported organic fertilizers creating a sludge that clogs irrigation lines and emitters,[21] requiring the use of line cleaners to clear it out.

Because organic fertilizers often don't completely decompose in hydroponic systems, phytotoxic compounds can accumulate. Dissolved oxygen also declines, and the combination can result in inhibited plant growth.[22] Moreover, fertilizers containing animal-derived sources tend to go rancid in recirculating systems.[23]

Finally, unlike the stability that organic fertilizers bring to soil pH, in hydroponic systems they tend to cause the pH to fluctuate.[24]

INSTANT ABSORPTION WITH INORGANIC FERTILIZERS

Inorganic fertilizers do not create these problems in hydroponic systems.

As we discussed earlier, plants can only take up nutrients in inorganic forms. So when hydroponic growers use inorganic fertilizers, they don't have to add any microbial inoculants for nutrient conversion. Plants can absorb the essential nutrients in inorganic fertilizers immediately. Because hydroponics are a controlled environment where there's no risk of nutrients being lost, there's no benefit to the slow release of nutrients typical of organic fertilizers.

Inorganic fertilizers also don't require as much pH management. In an experiment comparing an inorganic fertilizer with an organic fertilizer applied to hydroponically grown lettuce, the organic fertilizer caused wild pH swings. The pH often increased above 8, making nutrients unavailable to the plants. By contrast, the inorganic fertilizer required less pH adjusting, likely because of the pH buffer in

21 David Kuack, "Organic vs. traditional hydroponic production: the top 3 differences," Hort Americas; accessed June 1, 2021, https://hortamericas.com/blog/news/organic-vs-traditional-hydroponic-production-the-top-3-differences/#

22 Kazuki Kano et al., "Effects of Organic Fertilizer on Bok Choy Growth and Quality in Hydroponic Cultures," Agronomy 11 (2021): 491, https://doi.org/10.3390/agronomy11030491

23 Ibid.

24 Kimberly Williams, Olivier Francescangeli and Jason Nelson, "Using Organic Fertilizers in Hydroponics and Recirculating Culture," GPN magazine (2013); accessed June 1, 2021, https://gpnmag.com/article/using-organic-fertilizers-hydroponics-and-recirculating-culture/

the formulation.

The study also found that the inorganically fertilized lettuce had significantly higher fresh weight compared with the organically fertilized lettuce. Adjusting the pH of the nutrient solution of the inorganically fertilized lettuce did not significantly affect the fresh weight. However, it was necessary to adjust the pH in the nutrient solution of the organically fertilized lettuce to obtain higher fresh weight. Based on these results, the researchers advise using inorganic fertilizer for increased yields and a cleaner hydroponic system with less pH maintenance. [25]

Thanks to the absence of organic matter, hydroponic growers also don't have to worry about inorganic fertilizers going rancid or clogging the system.

For all these reasons, unless a grower is certified organic, or plans to become certified, there's no reason why they shouldn't consider including inorganic fertilizers in their hydroponic systems.

25 Ryan Ronzoni and Neil Mattson, "A Guide to Home Hydroponics for Leafy Greens," Cornell University (2020); accessed July 10, 2021, https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/8/8824/files/2020/05/Guide-To-Home-Hydroponics-For-Leafy-Greens.pdf

Unless a grower is certified organic, or plans to become certified, there's no reason why they shouldn't consider including inorganic fertilizers in their hydroponic systems.

WHY INORGANIC FERTILIZERS GOT A BAD NAME

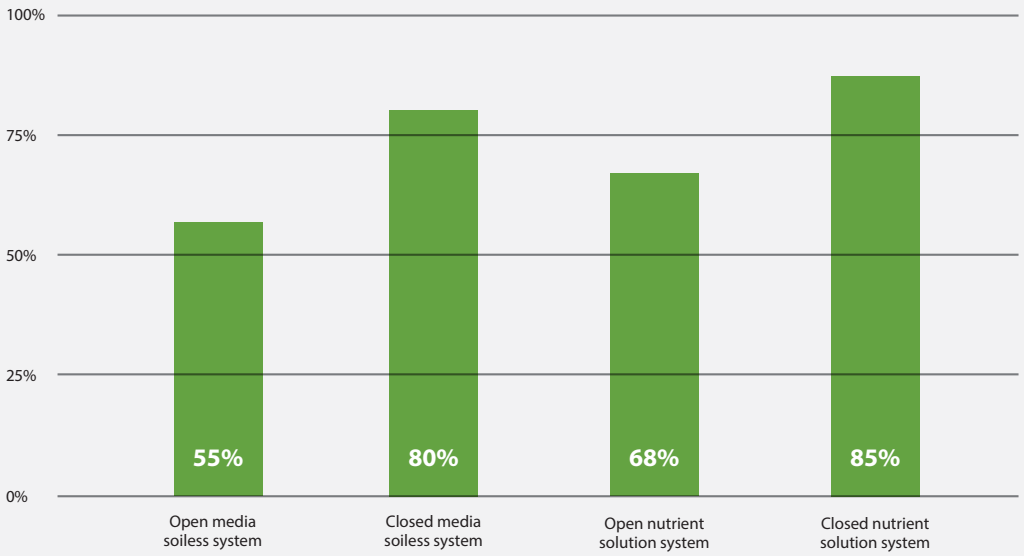
Given the benefits of inorganic fertilizers in hydroponic systems, it's natural to wonder why they have such a negative connotation attached to them. Again, it goes back to the differences between soil and soilless production systems.

One argument often made against inorganic fertilizers is that they pollute the environment. It's true that the dead zone in the Gulf of Mexico[26] and harmful algal blooms that plague freshwater bodies like Lake Erie are caused by nitrogen and phosphorus fertilizer runoff, respectively, from farm fields. But that doesn't mean that inorganic fertilizers are solely to blame. The Ohio Lake Erie Phosphorus Task Force, charged with identifying and evaluating the contributions of dissolved reactive phosphorus in Lake Erie, found a lack of evidence to differentiate the relative contributions of inorganic and organic fertilizers—in this case, commercial fertilizers versus manure. But it noted that commercial fertilizer use outweighed manure application and biosolids by a factor of two to one.[27]

26 "Treating Nitrates," USDA Natural Resources Conservation Service Iowa; accessed July 10, 2021, https://www.nrcs.usda.gov/wps/portal/nrcs/ia/technical/ecoscience/nutrient/nrcs142p2_008203/

27 "Ohio Lake Erie Phosphorus Task Force Final Report Executive Summary," Ohio Environmental Protection Agency (2010); accessed July 10, 2021, https://www.epa.state.oh.us/portals/35/lakeerie/ptaskforce/Task_Force_Final_Executive_Summary_April_2010.pdf

Figure 3. Percentage of fertilizer consumption in hydroponics compared with conventional farming



* Chart data source: Ali AlShrouf, "Hydroponics, Aeroponic and Aquaponics as Compared with Conventional Farming," American Scientific Research Journal for Engineering, Technology and Sciences, 27(1) (2017): 247-255, https://asrjetsjournal.org/index.php/American_Scientific_Journal/article/view/2543

In other words, inorganic fertilizers may be blamed more because they are used more.

Part of the reason for nutrient runoff from farm fields is the amount of fertilizer applied. One study found that about one third of annual nitrogen fertilizer applications made to US cornfields is just to compensate for the long-term loss of soil fertility caused by soil erosion and organic matter loss.[28] Excessive fertilization, whether of organic or inorganic fertilizers, increases the risk of environmental pollution, and it's why farmers are encouraged to match fertilizer needs to crop uptake.[29]

Hydroponics, by contrast, uses significantly less fertilizer—anywhere from 55 to 85 percent less than traditional farming, depending on the hydroponic system (see Figure 3). And, unlike traditional farmers, hydroponic growers can control what happens to their nutrient wastewater and prevent environmental harm by properly recycling or purifying it.[30]

There is also concern over the impact of inorganic fertilizers on human health. Some of it is due to the presence of heavy metals in some inorganic fertilizers. For example, cadmium can be found in fertilizers made from rock phosphate. However, scientific assessments show that trace amounts of cadmium in phosphorus fertilizers are safe and pose no risk to the general public or to the farmers who use them.[31]

The Environmental Protection Agency (EPA) has standards that limit the levels of heavy metals and other toxic compounds present in fertilizers made from hazardous waste.[32] The EPA believes that as long as they are properly manufactured and applied, and can safely and effectively substitute for virgin raw materials, some wastes can be used beneficially in fertilizers. However, the agency notes that a relatively small percentage of fertilizers are made from industrial waste, and those that are hazardous are only used in a small portion of those fertilizers.[33]

28 W.S. Jang et al., "The Hidden Costs of Land Degradation in US Maize Agriculture," Earth's Future 9(2) (2021): https://doi.org/10.1029/2020EF001641

29 "Source Water Protection Practices Bulletin Managing Agricultural Fertilizer Application to Prevent Contamination of Drinking Water," United States Environmental Protection Agency (2001); accessed July 10, 2021, https://extension.usu.edu/waterquality/files-ou/Agriculture-and-Water-Quality/fertilizer.pdf

30 "How Not to Dispose of Hydroponic Nutrients," GAIACA Waste Revitalization (2020); accessed July 10, 2021, https://www.gaiaca.com/dispose-hydroponic-nutrients/

31 Terry Roberts, "Cadmium and Phosphorus Fertilizers: The Issues and the Science," Procedia Engineering 83 (2014): 52-59, https://doi.org/10.1016/j.proeng.2014.09.012

32 To learn what heavy metals are present in a particular fertilizer product, and their amounts, visit aapfco.org/metals.

33 "Agriculture Nutrient Management and Fertilizer," United States Environmental Protection Agency; accessed June 1, 2021, https://www.epa.gov/agriculture/agriculture-nutrient-management-and-fertilizer

Other concerns stem from the idea that organic foods are healthier than conventionally grown foods. Again, it's important to remember that organically fertilizing a plant does not mean it is organically produced.

The evidence surrounding this belief is mixed. For instance, one meta-analysis looked at 237 studies and found no consistent differences between the vitamin content of organic and conventional foods. Phosphorus was the only nutrient higher in organic produce. Given that few people have a phosphorus deficiency, the researchers said this has little clinical significance.[34]

There are other health benefits of organic food, such as less pesticide residue.

But that goes back to the pesticide-free production methods of organic farming—not whether the plant was grown with organic or inorganic fertilizer.

However, another meta-analysis based on 343 peer-reviewed publications came to different conclusions. Researchers found that the concentration of antioxidants was significantly higher, and the concentration of cadmium significantly lower, in organic crops. They cite evidence that these results are connected to specific agronomic practices used in organic production, such as the absence of mineral and phosphorus fertilizers.[35]

Other studies only see a difference in nitrate concentrations. One survey measured nitrogen in vegetables available in US retail stores and found most organic vegetables had lower nitrate concentrations

34 Michelle Brandt, "Little evidence of health benefits from organic foods, study finds," Stanford Medicine News Center (2012); accessed July 10, 2021, https://med.stanford.edu/news/all-news/2012/09/little-evidence-of-health-benefits-from-organic-foods-study-finds.html

35 Marcin Barański et al., "Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: A systematic literature review and meta-analyses," British Journal of Nutrition, 112(5) (2014): 794-811, https://doi.org/10.1017/S0007114514001366

than their conventional counterparts.[36] A nine-year greenhouse study on edible plants—including tomatoes, beets, carrots and chard—that compared organic fertilizers with inorganic ones found the organically fertilized plants had lower nitrate concentration in their edible parts.[37]

There are other health benefits of organic food, such as less pesticide residue.[38] But that goes back to the pesticide-free production methods of organic farming—not whether the plant was grown with organic or inorganic fertilizer.

MAXIMIZE THE BENEFITS WITH BOTH

Unless you're certified organic, there's no need to swear off inorganic fertilizers. As we've discussed, they're easier to work with in hydroponic systems and provide plants the nutrients they need in the forms they can absorb for instant uptake.

But using inorganic fertilizers doesn't mean you need to avoid organic fertilizers and the benefits they offer. Instead, why not use both?

There are fertilizers that contain both high-quality inorganic minerals to provide plants with their basic nutrient needs and organic compounds to fill in dietary gaps and provide additional benefits.

Here are some tips on what to look for to ensure the nutrient products you choose benefit your hydroponic grow operation:

- **Make sure they're formulated for hydroponics.** Using greenhouse-grade fertilizers is crucial to avoiding clogs in pumps and irrigation lines. Organic fertilizer products must be soluble and not contain filler material designed for soil. Moreover, hydroponic fertilizer products may have higher calcium and magnesium and contain micronutrients, unlike most fertilizers used in fields.[39]

36 Maryuri Nunez de Gonzalez et al., "A Survey of Nitrate and Nitrite Concentrations in Conventional and Organic-Labeled Raw Vegetables at Retail," Journal of Food Science, 80(5) (2015): https://doi.org/10.1111/1750-3841.12858

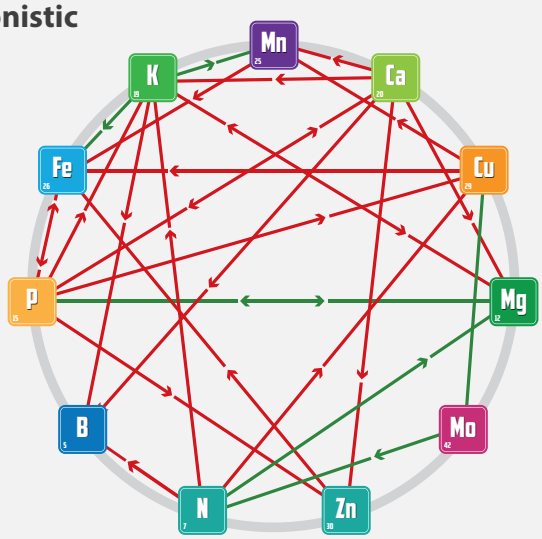
37 J. F. Herencia et al., "Comparison between Organic and Mineral Fertilization for Soil Fertility Levels, Crop Macronutrient Concentrations, and Yield," Agronomy Journal, 99 (2007): 973-983, https://doi.org/10.2134/agronj2006.0168

38 Ibid.

39 Natalie Bumgarner and Robert Hochmuth, "Leafy Crop Production in Small-Scale Soilless and Hydroponic System," University of Tennessee Institute of Agriculture (2019); accessed June 1, 2021; https://extension.tennessee.edu/publications/Documents/W844-B.pdf

- **Note the mineral content.**
  A base-nutrient fertilizer should contain all the essential plant nutrients at levels that meet plants' nutritional requirements. Keep in mind that if a fertilizer provides too little or too much of any nutrient, the plant will suffer a deficiency or possibly toxicity. Too little obviously means the plant isn't getting enough of that essential nutrient, but overfeeding can cause the nutrient to lock out or inhibit the uptake of one or more other nutrients (see Figure 4).

Figure 4. Mulder's chart shows the synergistic and antagonistic interactions between 11 of the essential plant nutrients.



Synergistic (positive): The nutrients help each other by aiding uptake or utilization.

Antagonistic (negative): The nutrients hinder each other in uptake or utilization.

For example: Adequate potassium (K) aids use of iron and manganese, but if it is too high it will hinder utilization of magnesium, boron, nitrogen, phosphorous and calcium.

- **Research the organic compounds.**
  What natural ingredients are in the product? More importantly, what do they do? Look for sources that are known to improve crop production. For example, kelp extract stimulates cellular growth, promotes plant strength, increases chlorophyll content and helps trigger early flowering and fruiting.

- **Check for chelation.**
  This may be in the form of chelated micronutrients or organic compounds such as humic acid. In either case, it will be stated on the label. By forming complexes that the plant roots can readily absorb, chelates help prevent nutrients from binding to the substrate or being lost as waste. They also extend the pH range of micronutrients to keep them absorbable for plants.

Emerald Harvest's complete line of nutrient products is formulated to maximize plant growth in the best way possible. That means using the best raw materias for the job—sometimes organic substances, other times natural minerals, and often a mixture of both.

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