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HO-351-W

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Organic Production in Greenhouses:

Fertilizer Basics and Recommendations

Background

Organic products are highly popular in the U.S. Consumers believe they are produced using inputs that do not harm the environment and consider them safe — and worth premium pricing. For example, organic romaine lettuce can cost 50% more than conventionally grown lettuce. The revenue from organic products was $6 billion in 2025 (IBIS World, 2025). Of this, nearly a third of revenue was from selling organic vegetables ($2 billion). The organic farming industry is projected to grow positively in the next five years (IBIS World).

Organic Label

Certification is required to sell agricultural products with an organic label. In the U.S., the process of certification is administered by the Department of Agriculture (USDA). Under the Organic Food Production Act (1990), the National Organic Program was established. This program implements organic certification for producers of organic products. An agricultural product is considered as organic if it is produced (i) without the use of prohibited synthetic or nonsynthetic materials, (ii) on land to which prohibited chemicals were not added in the three years preceding harvest, and (iii) in compliance with an organic plan agreed to between the producer or handler and certifying agent.

There are four categories of organic labels for crops.

1. 100% organic: Products must be made up of 100% certified organic ingredients.
2. Organic: Nonorganic ingredients may be used, but no more than 5% of the combined total.

Figure 1. Different categories of organic products that are sold in the U.S. market (Source: USDA)

3. Made with organic ingredients: Product must be made with at least 70% of certified organic ingredients. The organic seal cannot be used on the product, and the final product cannot be represented as organic.
4. Contain organic ingredients: Products with less than 70% certified organic content would fall under this category. These products don't need to be certified and cannot display the USDA organic seal or use the word organic on the principal display panel.

Greenhouse Organic Production

Crops grown in greenhouses (e.g., leafy greens and vegetables) can receive organic certification by the USDA. However, this requires that the crop is produced in a way that complies with the organic standard guidelines established by the agency. Information about organic certification guidelines can be found at the USDA website (Tipsheets on Certification Guidelines | Agricultural Marketing Service). Following are general considerations for receiving an organic label in greenhouse production:

(i). Prohibited substances (e.g., conventional pesticides) should not have been used in the greenhouse for at least three years prior to organic production.

(ii). Potting media should contain certified materials (e.g., peat) and not contain any fertilizers or wetting agents.

(iii). Fertilizers and pesticides used during production should be from the national list (certified by the Organic Materials Review Institute, OMRI). Water used during production should not contain prohibited substances.

(iv). Water used for washing produce may contain disinfectants on the national list (e.g., chlorine) within the accepted levels by the Food and Drug Administration and the Environmental Protection Agency.

(v). When both organic and conventional methods are used on the same farm, care should be taken not to comingle practices.

(vi). Records (e.g., crop history, production logs, purchase records, sale records, spray records, etc.) should be maintained for organic certification.

Organic Fertilizers

This article focuses on organic fertilizers used in greenhouse production. Organic fertilizers are made of plant, animal or mineral sources, such as fish emulsion, feather meal, composted manure, alfalfa meal, bone meal, worm castings, or molasses-based liquid fertilizers. Information related to available certified or listed organic fertilizers (and other products) that can be used in crop production is available to growers from the Organic Materials Review Institute (OMRI) website (OMRI Search | Organic Materials Review Institute). On this website, growers can select "OMRI listed products" for "the U.S. or Canada". They can also filter for products that are either completely allowed or allowed with some restrictions; the details on restrictions will be available on product labels. Further, growers can select for "crops" and choose fertilizers (CF), pesticides (CP), and tools (CT). It is important to know that, unlike conventional fertilizers, most of the available options for organic fertilizers contain a few (two or three) nutrients. Therefore, it is important to choose different organic fertilizers on the OMRI list to prepare a custom mix that can supply most of the plant nutrients.

Organic vs. Conventional Fertilizers in Greenhouse Production

Research at Purdue University compared organic fertilizers with conventional fertilizers in greenhouse lettuce production. The organic and conventional fertilizers used in the research contained similar quantities of different nutrients needed for plant growth. The study used lettuce seeds belonging to four groups (leaf, oak leaf, butterhead and romaine) and two colors (red and green), altogether eight different varieties. These seeds were sourced from organically grown plants. Lettuce plants were grown in peat-based soilless substrate containing vermiculite (4 parts peat to 1 part vermiculite) in which fertilizers were added at the start of the study. We used four-inch square pots to grow lettuce plants. In the study, reverse osmosis water containing no nutrients was used to grow lettuce plants to ensure no additional nutrients were supplied to plants through irrigation water.

Conventional fertilizer mix was custom-prepared using Osmocote and gypsum (Table 1) to contain most of the plant nutrients. Using the OMRI list, a select group of organic fertilizers was used to prepare a mix containing most of the plant nutrients. The different types of fertilizers and their quantities used to prepare custom conventional and organic fertilizers are shown in Table 1.

Table 1. Different conventional and organic fertilizers (identified from the OMRI list) used, plant nutrients provided by the fertilizers, and quantity of each fertilizer added to each cubic foot of substrate in the study.

Type	Fertilizer Components	Nutrients	oz/ft^3
Conventional	Osmocote 15-9-12	N, P, K, Mg, S, Fe, B, Cu, Mn, Mo, Zn	3.5
	Gypsum	Ca, S	0.5
	Total		4.0
Organic	7-5-7	N, P, K	6.6
	4-3-2	N, P, P, Ca	1.6
	Epsom Salt	Mg, S	0.5
	Ferrous Sulfate	Fe, S	0.2
	Manganese Sulfate	Mn, S	0.02
	Fertibor Boron	B	0.09
	Total		9.0

The above specific quantities of organic and conventional fertilizers were used to ensure that most of the macronutrients and some micronutrients in both organic and conventional fertilizer mixes are similar. Especially, more quantity (nearly 2.25 times) of organic fertilizer was needed to result in the similar amount of plant nutrients as in the conventional fertilizer because the nutrient concentration in organic fertilizers was low.

The resulting quantities of different elements added to the substrate in each pot from conventional and organic mixes is shown in Table 2. Although some elements, such as P_2O_5 and S, were lower in organic mix, and others, like Fe and B, were lower in the conventional mix, the quantities were within the normal range recommended for lettuce plants. The prepared organic mix did not contain certain micronutrients, including copper, zinc, molybdenum, chlorine, and nickel. However, it is likely that they are present as trace impurities in the added fertilizers.

Table 2. Quantity (grams) of different elements in the custom-prepared conventional and organic fertilizer mixes per cubic foot of substrate. For conversion to ounces, use 1 ounce = 28.35 grams.

Fertilizer	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Mn	Mo	B	Cu	Zn
	g/ft^3											
Conventional	14.7	8.8	11.8	2.9	1.3	7.9	0.45	0.06	0.02	0.02	0.05	0.05
Organic	19.9	4.6	11.6	3.2	1.3	2.4	0.95	0.07	-	0.35	-	-

Lettuce plants were grown for 30 days with either organic or conventional fertilizer mixes, as shown in Table 1. No additional nutrients were added to the substrate during production. After 30 days, plants were harvested and their fresh weight was measured. The study found that the fresh weight of most lettuce varieties tested was higher with conventional than organic fertilizer mix (Figure 2). The extent of difference in weight between conventional and organic fertilizers changed with variety. Some varieties of romaine, butterhead and leaf groups showed large differences, while the oakleaf group showed smaller differences.

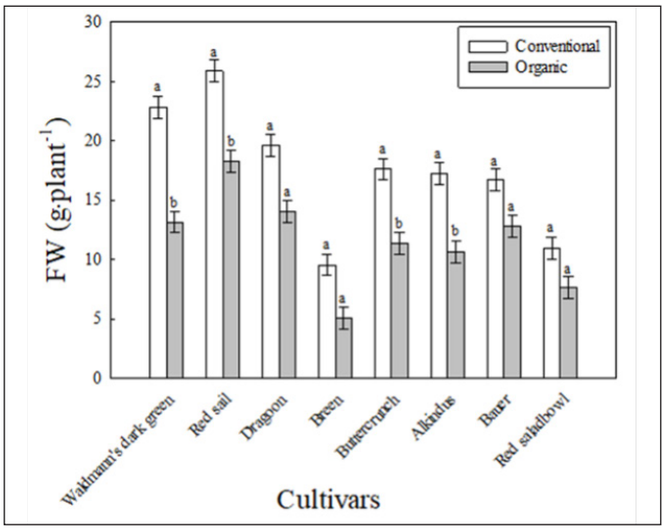

Figure 2. Average yields of lettuce varieties grown with custom-prepared conventional and organic fertilizers with similar amounts of nutrients. (Graph adapted from a research paper published by Sangrak Son and Krishna Nemali in 2026, https://doi.org/10.3389/fpls.2026.1785126).

To identify the reason for the reduced yield of lettuce grown with organic fertilizer, electrical conductivity (EC) of the substrate (a measure of nutrient concentration in the rootzone) was measured. Each pot was thoroughly irrigated with reverse osmosis water an hour before being placing in a funnel that was inserted into a plastic tube (Figure 3, left). A small volume (50 ml) of reverse osmosis water was applied to the top of the substrate. The additional water pushed the existing water in the rootzone through the bottom holes and was collected as leachate in the tube. The EC of the leachate was measured to quantify the concentration of nutrients in the root zone. It was much lower in the substrate supplied with organic fertilizer (Figure 3, right). This means that root zone of plants grown with organic fertilizer, despite containing similar quantities of nutrients, did not contain enough nutrients as the plants grown with the conventional fertilizer.

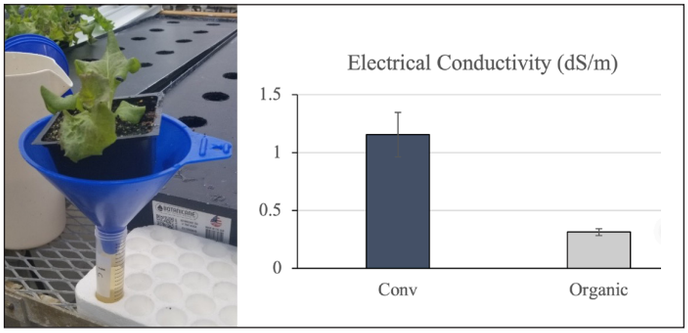

Figure 3. Pour-thru method of determining electrical conductivity of the substrate (left). Difference in electrical conductivity of the substrate between conventional and organic fertilizers (right).

Lower concentration of nutrients in the root zone is likely the main reason for lower yield of lettuce plants. Organic fertilizers naturally contain low nutrient concentrations and gradually release nutrients to the substrate from microbial activity (Figure 4). Microbial mineralization is essential to convert organic nitrogen into plant-available forms [ammoniacal ($NH4^+$) and nitrate ($NO3^-$]. Microbial growth is influenced by temperature of the substrate, with maximum growth happening when substrate temperature is around 85 to 90 degrees F. The slow nutrient release from organic fertilizers can reduce the risk of nutrient leaching out of the substrate in containers. However, this can also result in low nutrient delivery to plants compared to conventional fertilizers. If the decomposition of organic fertilizers is relatively slow and delays nutrient availability to plants during the rapid vegetative growth phase, it can lead to yield loss.

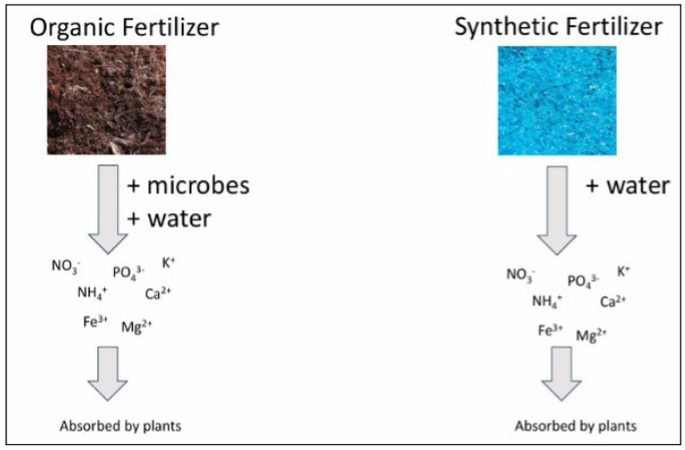

Figure 4. A schematic of the general process of nutrient release from organic and conventional fertilizers in the substrate. Note that nutrients get readily soluble in substrate solution and become available to plants when using a synthetic or conventional fertilizer. However, organic materials should be decomposed by bacterial growth and at specific temperature before they are able to release nutrients into soil solution for plant absorption. This extra step can delay nutrient availability to plants when using organic fertilizers.

Because of delay in nutrient decomposition and release, the general recommendation is to add organic fertilizers to natural soil at least three months prior to crop production. However, this may not be practical in greenhouse production. A large space is needed to store substrate with organic fertilizer for three months, during which nutrients may slowly leach. Moreover, the storage needs to be maintained at a warm temperature for bacterial growth. Nutrient concentration should be regularly monitored for stored substrate, and pH should be maintained.

Organic Liquid Fertilizers

Another method to increase yield in greenhouse organic production is to supplement substrate-incorporated organic fertilizer with organic liquid fertilizer. Organic liquid fertilizers are made of materials such as agricultural manures and fish byproducts. During the manufacturing process, they undergo fermentation, enzymatic hydrolysis, and anaerobic digestion processes that break down organic materials and increase the concentration of readily available nutrients. After the manufacturing process, organic nutrients are in a stable condition; further microbial activity is halted by low pH or a thermal process for storage purposes.

A separate study was conducted to investigate the effect of supplementing organic liquid fertilizer on lettuce yield. The plants were grown with one of the three fertilizers including, 2 g/pot of conventional fertilizer, 2 g/pot of organic fertilizer, and 2 g/pot of organic fertilizer plus once-a-week application of 100 mL of organic liquid fertilizer. The organic liquid fertilizer was prepared by mixing 10 mL of concentrate per liter of reverse osmosis water. The quantity of organic fertilizer incorporated into the substrate was reduced to 2 g to slightly offset fertilizer costs when organic liquid fertilizer was added. The composition of conventional and organic fertilizers incorporated into the substrate at the start of the experiment was identical to those shown in Table 1. The organic liquid fertilizer contained N-P-K percentages of 3-3-2. Information about the type of nitrogen, phosphorus and potassium present in the liquid organic fertilizer was not available on the product label. As expected, the yield of lettuce was lower with organic than conventional fertilizer, much lower than what was observed in the previous study due to half the quantity of organic fertilizer used in the present study. However, supplementation with organic liquid fertilizer significantly improved lettuce yield (Figure 5).

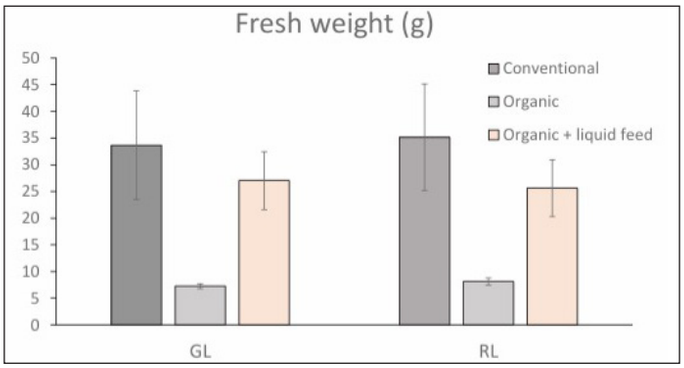

Figure 5. Fresh weight of green leaf (GL) and red leaf (RL) lettuce plants per pot after four weeks of growth with 2 g/pot of conventional fertilizer, 2 g/pot of organic fertilizer, and 2 g/pot of organic fertilizer plus once-a-week application of 10 mL per liter of organic liquid fertilizer.

Although the fresh weight of lettuce with organic liquid fertilizer supplementation was slightly lower than that of conventional fertilizer, the improvement in fresh weight with addition of a small volume of organic N, P, and K through the liquid feed was large. Organic liquid fertilizers can be applied at any time during production. However, they may be most useful when applied during the first two weeks of lettuce growth to ensure that there are enough nutrients in the substrate when rapid growth starts during the third week in greenhouses.

In summary, the research-based information supports that organic fertilizers, when incorporated into the substrate, can release nutrients slowly and reduce yields. Supplementation with organic liquid fertilizer during production is necessary to increase lettuce yield in greenhouse-based organic farming systems. Growers are encouraged to contact the author, Krishna Nemali (knemali@purdue.edu), for more information.

August 2026