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Understanding Fertilizers and Soil Amendments[1]

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Introduction

Fertilizers play a crucial role in modern agriculture, supplying essential nutrients that enhance crop growth and productivity. Choosing the right fertilizer/amendment type (organic or inorganic/synthetic) can impact soil health, plant vigor, environmental sustainability, and overall farm profitability. This guide provides a comparison of organic fertilizers/amendments and inorganic/synthetic fertilizers/amendments, covering their differences, advantages, disadvantages, and impacts on soil to aid growers in making informed decisions. This publication is intended for growers, Extension faculty, environmental stewards, crop consultants, certified crop advisors, gardeners, and students interested in crop production.

Organic Fertilizers

Organic fertilizers are derived from natural sources, such as plant materials and animals or their byproducts. They release nutrients directly or gradually as they decompose. However, to satisfy crop needs and reduce environmental impacts, organic fertilizer must be selected for specific purposes based on available nutrients in the soil, the type of organic fertilizer, and the release pattern of nutrients from the specific organic fertilizers to be applied. After the organic fertilizer is applied, it is crucial to do periodic crop monitoring to avoid nutrient deficiencies. While organic fertilizers typically contain lower concentrations of nutrients, they provide a wider range of macro- and micronutrients. For example, fish emulsion not only provides nitrogen, phosphorus, potassium, iron, zinc, etc., but also many amino acids. Additionally, organic fertilizers improve soil physical properties, such as promoting the formation of soil aggregates, and supporting a rich microbial environment that is conducive to nutrient cycling (Kang et al. 2011; Li et al. 2008). However, organic fertilizers often require larger quantities to meet the high nutrient needs of crops, and their bulkiness can make transport and application more labor-intensive. Additionally, the nutrient concentration can vary by source, necessitating careful testing and management. Different types of organic fertilizers can be selected based on the content of specific nutrients. For example, blood meals and chicken feather meals are good sources of N with the capacity to supply up to 12% N (Gaskell et al. 2007). Bone meal can slowly release a reasonable amount of P as it contains 15% P_2O_5 (Gaskell et al. 2007). Table 1 presents common organic material and their N, P, and K content.

Organic Amendments

Organic amendments are plant- or animal-derived materials primarily used to enhance soil health by increasing the organic matter content, modifying the soil's pH, improving its structure, stimulating microbial activity, and providing other benefits to the soil. Organic amendments include compost, biochar, or any other animal-/plant-based materials that can be applied to improve soil health (Elmeknassi et al. 2024). Organic amendments may also supply nutrients in small quantities due to their low nutrient contents. For example, wood ash and biochar have reasonable amounts of Ca and K, but are very low in other nutrients (Moragues-Saitua et al. 2023; Reed et al. 2017). Compost can provide certain nutrients in small amounts while primarily enhancing soil organic matter, which, in turn, improves soil nutrient retention and increases water-holding capacity (Al-Bataina et al. 2016). The improved microbial activity stimulated by organic amendments accelerates nutrient cycling, making nutrients more available to plants, and contributes to a resilient, productive soil ecosystem (Wei et al. 2021). Organic amendments also contribute to carbon sequestration by storing carbon in soil organic matter, thereby helping to mitigate the impacts of climate change (Li et al. 2024).

How Costly Are Organic Fertilizers/Amendments?

Organic fertilizers/amendments may be more expensive initially because they often come from labor-intensive processes involving composting, incineration, pyrolysis, transportation, or the specialized production of organic materials such as fish or bone meals.

Synthetic/Inorganic Fertilizers

Most inorganic fertilizers are inorganic salts that provide readily soluble plant nutrients. They are manufactured through chemical processes, often using nonrenewable resources such as minerals or synthesized chemicals, or using atmospheric N_2 through high-energy input processes. Unlike organic fertilizers, which supply a broad range of nutrients and organic matter, synthetic fertilizers usually contain a few key nutrients, such as nitrogen, phosphorus, potassium, sulfur, and occasionally some micronutrients, unless they are intentionally blended. Their fast-release nature supports rapid crop growth and allows precise application due to consistent nutrient formulations. However, with advances in technology, slow-release or controlled-release fertilizers have become available. Additionally, nitrification inhibitors are often added to nitrogen-containing synthetic fertilizers so that the process of nitrification is delayed. These fertilizer technologies help to extend the availability of nutrients for a longer period. An advantage to synthetic fertilizers is that concentration allows for simpler transportation and applications, especially for large-scale operations. However, prolonged use of synthetic fertilizers can degrade soil health by reducing organic matter, compacting soil, and diminishing microbial activity, which can increase susceptibility to erosion. Moreover, ammonium-based fertilizers could have a higher potential for soil acidification, and care must be given for possible soil acidification after the use of ammonia-based fertilizers. Additionally, synthetic fertilizers have environmental risks, including nutrient leaching and runoff that contaminates water bodies and contributes to eutrophication. Long-term use can also lead to salt buildup in soil, potentially reducing crop tolerance and harming sensitive plants. Overdependence on chemical fertilizers in the long run suppresses microbial activity in the cropping system, disrupts soil pH balance, and encourages pest proliferation (Pahalvi et al. 2021).

What Are the Main Inorganic Fertilizers?

Nitrogen fertilizers are produced through the Haber process, which synthesizes ammonia gas (NH_3) from natural gas and atmospheric nitrogen (N_2) under high temperatures and pressures. This method requires significant energy, often derived from fossil fuels. The energy-intensive process has reshaped the global nitrogen cycle and led to the establishment of nitrogen fertilizer factories near natural gas fields in countries such as Russia, China, India, Nigeria, and the United States. The most common sources of N fertilizers are ammonium nitrate, ammonium sulfate, urea, and urea-ammonium nitrate, and their respective contents of P_2O_5 are presented in Table 2. Some other fertilizers that are the main sources of P, such as diammonium phosphate, monoammonium phosphate, and ammonium polyphosphate, also contain N. Nitrogen fertilizers are known to induce acidity near their application spot. Therefore, possible changes in pH must be considered prior to the use of ammonia-based fertilizers.

Phosphorus fertilizers are made by treating phosphate rock (apatite) with sulfuric acid, with major reserves located primarily in Morocco, China, and the United States. The most common types of P fertilizers are monoammonium phosphate, diammonium phosphate, ammonium polyphosphate, rock phosphate, superphosphate, and concentrated superphosphate. The respective content of P_2O_5 for each is presented in Table 2.

Potassium fertilizers are derived from purifying naturally occurring salts from ancient seabed deposits, with notable sources in Canada, France, Germany, Russia, and the United States. The most common potassium fertilizers are potassium chloride, sulfate of potash (SOP), potassium sulfate, potassium-magnesium sulfate, potassium thiosulfate, and potassium nitrate, and their respective contents of P_2O_5 are presented in Table 2.

Inorganic Amendments

Inorganic amendments are materials such as lime, gypsum, sand, vermiculite, and perlite that can improve soil chemistry, texture, structure, and/or aeration (Banitalebi et al. 2019; Pan et al. 2020). Lime is the most important inorganic amendment, which is widely used to combat soil acidification (Adamu et al. 2025; Anikwe et al. 2016; Vieira Fontoura et al. 2019). In alkaline soil, the application of elemental sulfur is useful for reducing the soil pH to the desired level. A detailed recommendation of elemental sulfur in sugarcane production can be found in #SS-AGR-429, and #SL437 provides general information about elemental sulfur application in alkaline or calcareous soils. Gypsum is one of the most common inorganic amendments, which helps to combat salinity by displacing sodium from the negatively charged soil sorption sites (Elmeknassi et al. 2024).

How Costly Are Inorganic Fertilizers?

Inorganic/synthetic fertilizers tend to be cheaper initially due to the high nutrient concentration and lower transportation and application costs. However, frequent applications are needed. Additionally, they can lead to soil degradation and require soil amendments over time to maintain fertility, which may increase costs. For instance, ongoing applications of lime may be needed to offset the acidifying effects of synthetic ammoniacal or ammonium-forming nitrogen fertilizers.

Key Application Practices for Organic/Inorganic Fertilizers/Amendments

- Identify which organic fertilizers to use based on the intended function. The 4R nutrient stewardship principles can be applied by choosing the right source

(i.e., organic/inorganic fertilizer/amendment), based on the needed function. Applying at the right rate based on soil test results and nutrient contents of the organic fertilizers/amendments and the soil is essential to attain optimal crop yield and safeguard the environment. Applying at the right time with the right placement is crucial in achieving the expected results from the use of organic fertilizers/amendments.
- If you are applying organic amendments such as compost/manure, use well-decomposed material to avoid plant burn and improve nutrient availability. Do not apply fresh and undecomposed material, which may be high in temperature, levels of ammonia, weeds, and pathogens.
- Material intended for use as a source of fertilizer materials (e.g., solid manure) must be applied several weeks before planting to allow decomposition and nutrient release.
- Incorporate nitrogen fertilizers into the soil to minimize ammonia volatilization losses.
- For organic fertilizers, you may consider top-dressing for perennial crops to support gradual nutrient uptake.

For detailed information on the 4R nutrient stewardship principles, consult Ask IFAS publication #SL411. Several EDIS publications regarding inorganic fertilizer application rates, calculating the ideal rates, and criteria to be considered are available on Ask IFAS at https://edis.ifas.ufl.edu/. Some relevant publication examples are #SL315, #SL522, #SL 303, #CV296, #SL343, #HS1465, #SL486, and #HS941.

Choosing between Organic and Synthetic Fertilizers

A comparison of organic fertilizers/amendments and inorganic/synthetic fertilizers/amendments is presented in Table 3. Organic fertilizers are ideal for long-growing or perennial crops that benefit from gradual nutrient release. For high-yield, short-cycle crops, synthetic fertilizers may provide the rapid nutrient availability needed to achieve maximum productivity. Both organic and inorganic/synthetic fertilizers can be combined for better results in improving soil health while retaining and releasing a reasonable amount of nutrients to the crop.

If soil health is inadequate or lacking organic matter, organic amendments can be beneficial in building structure, improving fertility, and promoting microbial diversity (Mylavarapu and Zinati 2009). Inorganic/synthetic fertilizers can supplement nutrients effectively but may not enhance soil health over time.

Environmental considerations: Organic fertilizers/amendments align with eco-friendly practices by supporting healthy soil ecosystems and reducing pollution risks if properly selected and used. Inorganic/synthetic fertilizers, while effective, should be managed carefully to prevent leaching, runoff, and environmental impact.

Budget and management strategy: In the short term, synthetic fertilizers may be more economical, especially for meeting immediate nutrient needs. However, organic fertilizers can offer cost savings over the long term by improving soil health, increasing natural fertility and nutrient retention of the soil, and potentially increasing nutrient use efficiency from inorganic fertilizers.

Integrating Both Fertilizer Types: Best Practices

Combining organic and inorganic fertilizers/amendments through integrated nutrient management can provide a balanced approach that enhances productivity while promoting soil health. By using inorganic/synthetic fertilizers to meet immediate nutrient demands and organic fertilizers to build soil organic matter, growers can achieve sustained yields while reducing environmental impact. For example, using inorganic/synthetic nitrogen fertilizers in small doses to meet peak crop needs, supplemented with compost or manure to maintain soil health, can optimize both plant and soil health outcomes.

Handling and Storing Inorganic and Organic Fertilizers/Amendments

Proper storage and handling of organic fertilizers/amendments are crucial to ensure safety, reduce losses, and maintain product quality.

- For manures and compost: Store in covered areas to prevent nutrient loss through leaching and runoff. Reduce exposure to heat to reduce volatilization and/or denitrification. After extended storage, a test is needed to reevaluate the concentration of nutrients in the manure or compost.
- Avoid dust. In the case of biochar, applying a small quantity of water reduces dust.
- For inorganic fertilizers, store in airtight containers to avoid moisture absorption and caking.
- Blended fertilizers: Prevent mixing with incompatible chemicals to avoid nutrient loss. For example, mixing phosphorus fertilizers with micronutrients can potentially form insoluble compounds from which the plant cannot easily get nutrients. The rule of thumb for mixing fertilizers without prior knowledge is to mix them in small jars before large mixing, especially when combining liquid to liquid or liquid to solid fertilizers.

Conclusion

Selecting the right fertilizer type requires balancing immediate crop needs, long-term soil health, environmental stewardship, and financial considerations. Organic fertilizers offer long-term soil benefits and sustainability, while synthetic fertilizers provide rapid nutrient availability and cost efficiency. By understanding the advantages and limitations of each fertilizer type, growers can make informed decisions that enhance productivity, support soil health, protect the environment, and foster resilient agroecosystems.

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Table 1. Content of N, P, and K in some organic fertilizers/amendments.

Source	N (%)	P_2O_5 (%)	K_2O (%)
Blood meals	12	1–2	0–1
Fish meal	6–12	3–7	2–5
Chicken feather	12	0	0
Bone meal	1–6	11–30	0
Adapted from Utah State University Cooperative Extension (Koenig and Johnson 2011).			

Table 2. Content of nutrients in certain inorganic/synthetic fertilizers.

Source	N (%)	P_2O_5 (%)	K_2O (%)
Anhydrous ammonia	82	0	0
Urea	46	0	0
Ammonium nitrate	33.5–34	0	0
Urea-ammonium nitrate	28–32	0	0
Ammonium sulfate	21	0	0
Sodium nitrate	16	0	0
Ammonium thiosulfate	12	0	0
Monoammonium phosphate (MAP)	11	48–55	0
Diammonium phosphate (DAP)	18	47	0
Triple super phosphate (TSP)	0	46	0
Ammonium polyphosphate (APP)	10	34	0
Rock phosphate	0	34	3
Single superphosphate (SSP)	0	14–20	0
Potassium chloride	0	0	60–62
Sulfate of potash (SOP)	0	0	50
Potassium sulfate	0	0	50
Potassium nitrate	13.5	0	44
Potassium-magnesium sulfate	0	0	20
Potassium thiosulfate	0	0	17
Adapted from Mississippi State University Extension (Bryant et al. 2024).			

Table 3. Comparison of organic fertilizers/amendments and inorganic (synthetic) fertilizers/amendments.

Category	Organic Fertilizers/Amendments	Inorganic (Synthetic) Fertilizers/Amendments
Source	Derived from plant or animal materials	Produced through industrial chemical processes
Nutrient content	Typically lower, with a broader spectrum (macro + micronutrients), slow-release	High and concentrated in N, P, K; usually fast-release unless in a controlled-release formulation
Nutrient release pattern	Gradual release through decomposition and microbial activity	Immediate availability; some slow-release or stabilized forms available
Soil health effects	Enhance soil structure, microbial activity, and organic matter content	May degrade soil over time (reduced microbial activity, increased compaction, salt accumulation)

Category	Organic Fertilizers/Amendments	Inorganic (Synthetic) Fertilizers/Amendments
Environmental impact	Generally eco-friendly with proper use; improve sustainability	Higher risk of leaching, runoff, eutrophication, and soil acidification if overused
Cost	Higher initial cost, labor-intensive to produce, transport, and apply	Lower initial cost, efficient in transportation and application; however, long-term soil degradation may add cost
Application considerations	Require careful management due to variable nutrient content; preplant incorporation is preferred	Precise application is possible due to standardized content; it may require soil pH correction over time
Storage and handling	Require protection from heat and water; nutrient loss can occur during storage (e.g., compost, manure)	Must be kept dry to avoid caking; some incompatibility in blending requires caution
Amendment effects	Improve pH balance, aeration, microbial activity, and water-holding capacity	Lime for pH correction; gypsum for sodicity; sand, vermiculite, and perlite for texture and drainage
Integration potential	Excellent for integrated nutrient management when combined with inorganic/synthetic fertilizers	Effective when used alongside organic fertilizers/amendments for balanced nutrient uptake and maintaining soil health

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