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Green Fertilizers in Climate-Smart Farming

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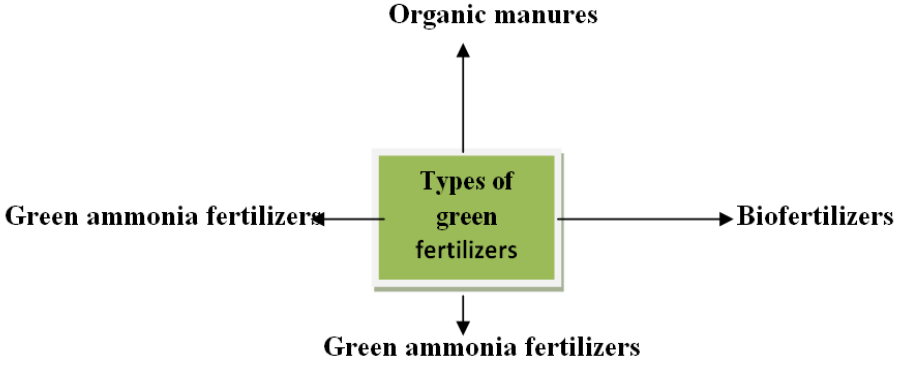
Green fertilizers can refer to sustainably produced ammonia (made using renewable energy and green hydrogen), bio-organic plant foods, or agricultural cover crops. These eco-friendly alternatives cut carbon emissions and improve soil health. The majority of nitrogen-based fertilizer could be supplied by renewable-energy-driven, small-scale technologies. Nitrogen fertilizers are made by turning atmospheric nitrogen and fossil-fuel-derived hydrogen into ammonia using an energy-intensive technique that was developed in the early 20th century called the Haber Bosch process. Right now, nitrogen fertilizers that are synthesized in this manner are used to grow food that feeds 3.8 billion people, or half of the global population."Nitrogen fertilizers are the largest contributor to both costs and greenhouse gas emissions in cropland agriculture. It's clear that transformative measures are required to achieve the goal of net-zero carbon emissions by 2050, while simultaneously reducing costs,"

Green fertilizers are environmentally friendly fertilizers produced or used in ways that reduce pollution, greenhouse gas emissions, and soil damage while supporting sustainable agriculture. They are designed to improve crop growth with less environmental impact than conventional chemical fertilizers. One of the key benefits of green plant organic fertilizer is its ability to improve soil structure. By adding organic matter to the soil, this fertilizer helps to retain moisture, improve aeration, and promote the growth of beneficial microorganisms. This results in healthier plants with stronger root systems and better resistance to pests and diseases. In addition to improving soil structure, green plant organic fertilizer also provides essential nutrients for plant growth. Unlike chemical fertilizers, which can lead to nutrient imbalances and soil degradation, organic fertilizers release nutrients slowly and steadily, providing plants with a consistent and long-lasting source of nourishment. Another advantage of green plant organic fertilizer is its environmental friendliness.

Types of green fertilizers



Organic manures: Organic manures boost soil fertility by enhancing physical structure, increasing water-holding capacity, and stimulating microbial activity. Unlike chemical fertilizers, they release nutrients slowly, building long-term soil health. Integrating manures with inorganic fertilizers optimizes fertility and significantly increases crop yields.

All organic residues incorporated into the soil undergo decomposition from the original residues, a series of products are formed. As the original material and the initial products undergo further decomposition, they become a brown black organic complex known by the name humus. Humus remain in dynamic yet fairly stable state. It is under continual attack by soil microorganisms. Decomposition and synthesis by microbial processes occur simultaneously, the rate depending on the nature and abundance of microorganisms involved, the moisture content, temperature, pH, aeration, quantity of freshly added organic matter and the extent of availability of carbon, nitrogen, phosphorus and potassium. Chemically humus has been characterized as ligno-protein or ligno-acid complex containing approximately 45 percent lignin compounds, 35 percent amino acids, 11 percent carbohydrates (4 percent cellulose, 7 percent hemicelluloses) 3 percent fats, waxes and resins and 6 percent other miscellaneous substances.

Biofertilizers: Bio fertilizers are active stains of microorganisms capable to fix atmospheric nitrogen to the soil. Bio fertilizers are eco-friendly agricultural inputs containing living microorganisms (bacteria, fungi, or algae) that colonize the rhizosphere or plant roots. They boost plant growth naturally by fixing atmospheric nitrogen, solubilizing soil phosphorus, and synthesizing essential growth hormones.

- ✓ **Nitrogen-Fixing:** Convert atmospheric nitrogen into ammonia for plant absorption (e.g., *Rhizobium*, *Azotobacter*, *Azospirillum*, and Cyanobacteria).
- ✓ **Phosphorus-Solubilizing:** Produce organic acids that break down insoluble soil phosphates into accessible forms (e.g., *Bacillus megaterium* and *Pseudomonas*).
- ✓ **Mycorrhiza (VAM):** Fungi that form symbiotic relationships with plant roots, expanding the root network to significantly enhance water and nutrient absorption, especially phosphorus.

Green ammonia fertilizers: Green ammonia is a sustainable, carbon-free alternative to traditional ammonia-based fertilizers. It is produced using renewable electricity (such as solar or wind) to extract hydrogen from water via electrolysis. This green hydrogen is then combined with nitrogen from the air using the Haber-Bosch process to synthesize ammonia. **Zero carbon ammonia, called "green ammonia,"** uses renewable energy to power electrolysis to produce hydrogen from water (replacing the steam methane reforming process based on hydrocarbon feedstocks) and the subsequent ammonia synthesis.

The advantage of green ammonia is the fact there is close to zero carbon-dioxide emission into the atmosphere. However the cost of making green ammonia is very high today compared to brown ammonia due to two major cost-components: a) electrolyzer and b) green power. Storage of hydrogen, separated using electrolysis of water, is also a challenge today leading to disruption of a continuous supply of feedstock to the ammonia plants.

Slow-Release Fertilizers: Slow-release fertilizers (SRFs) provide a steady, continuous supply of nutrients to plants over weeks or months. Unlike quick-release chemical fertilizers, they minimize root burn and nutrient runoff. Popular formulations range from organic meals to resin-coated granules (often referred to as Controlled Release Fertilizers) that release nutrients based on soil temperature and moisture

Plant productivity achieved by organic and bio-fertilizers is low compared to mineral fertilizers. Therefore, although claimed to be environmentally and ecologically sustainable, organic and bio-fertilizers suffer from several drawbacks, such as low concentration of nutrients, leading to the need for large amounts of organic and bio-fertilizer to be transported and stored inconsistent quality depending upon the source; low availability of nutrients, etc. Similarly, several management approaches, such as biochars, compost, organic manures, mulching, cover crops, crop residues, zero-tillage, agro-forestry, and crop diversification, are commonly recommended to improve soil carbon content while also managing soil nutrient.

The application of biochar also resulted in secondary benefits such as increased fertilizer efficiency and nutrient savings.

Conclusion

Traditional chemical fertilizers release large amounts of carbon dioxide and nitrous oxide. While using the green fertilizers we can reduce the fossil fuel and lower emissions. These helps to mitigate the climate change. Thus, they play a major role in achieving sustainable and climate-resilient farming systems, especially in dry and vulnerable agricultural regions.