AgriSustain
Agriculture

Review

Green Manuring: A Sustainable Path to Improve Soil Health and Fertility

Sunil Kumar Prajapati*, Parmeswar Dayal, Vipin Kumar, Ananya Gairola

Division of Agronomy, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi 110012, India

*Corresponding Author: sunil01673@gmail.com

Abstract

Soil health and fertility are fundamental pillars of sustainable agriculture, ensuring long-term productivity and environmental integrity. Green manuring, a practice rooted in agroecological principles, has gained recognition as an effective and sustainable strategy to enhance soil quality. This abstract provides an overview of the concept of green manuring, its benefits, and its role in promoting sustainable agriculture. It involves planting specific cover crops, often legumes or nitrogen-fixing plants, in between cash crops or during fallow periods. These cover crops are then incorporated into the soil, enriching it with organic matter and vital nutrients. The symbiotic relationship between certain cover crops and soil microorganisms allows for the fixation of atmospheric nitrogen, reducing the need for synthetic fertilizers and mitigating the environmental impact of excess nitrogen use. The advantages of green manuring extend beyond soil fertility. This practice enhances soil structure, water retention, and reduces erosion, all of which contribute to improved soil health. The addition of organic matter boosts microbial diversity, leading to increased nutrient cycling and a reduction in soil borne diseases. It also plays a pivotal role in carbon sequestration, contributing to climate change mitigation by storing carbon in the soil. This abstract emphasizes the importance of green manuring as a sustainable solution for enhancing soil health and fertility. Its ability to reduce the reliance on chemical inputs, conserve water, and sequester carbon makes it an invaluable practice for modern agriculture. To maximize the potential of green manuring, farmers must tailor their cover crop choices to their specific agroecological context and integrate it into their crop rotation systems. Further research and knowledge sharing are essential to support the adoption and optimization of green manuring for a sustainable and resilient agricultural future.

Keywords: Organic and Green Manure.

Introduction

Green manure is a valuable agricultural practice that involves the incorporation of fresh, undecomposed plant material into the soil to improve its fertility and overall health [1]. This organic material, often referred to as "green manure," is derived from two primary sources: the cultivation of specific green manure crops or the collection of green leaves and twigs from plants found in wastelands, field bunds, and forests. The concept of green manure is deeply rooted in sustainable farming techniques, emphasizing the use of natural resources to enhance soil quality and promote crop growth [2]. This practice not only enriches the soil with essential nutrients but also helps in weed suppression, erosion control, and the enhancement of microbial activity within the soil. Green manure crops, such as legumes (e.g., clover, alfalfa, and soybeans) and other

OPEN ACCESS

CITATION

Prajapati, S.K.; Dayal, P.; Kumar, V.; Gairola, A. Green Manuring: A Sustainable Path to Improve Soil Health and Fertility. *AgriSustain-an International Journal,* 2023, 01(2), 24-33.

ARTICLE INFORMATION

Received: May 2023
Revised : May 2023
Accepted: June 2023

DOI: 10.5281/zenodo.10049824

nitrogen-fixing plants (e.g., vetch and lupins), are intentionally grown in agricultural fields during fallow periods or between cash crops [3]. These crops have the unique ability to capture atmospheric nitrogen and convert it into a form that is readily available for subsequent crops, reducing the need for synthetic nitrogen fertilizers. Once these crops reach maturity, they are tilled back into the soil, replenishing it with organic matter and nutrients. Alternatively, green manure can also be sourced from the leaves and twigs of wild plants that grow in non-cultivated areas like wastelands, field boundaries, and forests. These plant materials are collected and incorporated into the soil to mimic the benefits of cultivated green manure crops. This method not only helps in recycling natural resources but also aids in maintaining biodiversity and preventing the spread of invasive species. Green manure plays a pivotal role in sustainable agriculture, contributing to soil enrichment, fertility improvement, and environmental conservation. Whether through the cultivation of specific crops or the utilization of wild plant material, the practice of green manure underscores the importance of harnessing nature's inherent processes to support productive and eco-friendly farming practices.

History of green manuring

The value of green manure was recognized by farmers in India for thousands of years, as mentioned in treatises like Vriksh Ayurveda. In Ancient Greece too, farmers ploughed broad bean plants into the soil. Chinese agricultural texts dating back hundreds of years refer to the importance of grasses and weeds in providing nutrients for farm soil. It was also known to early North American colonists arriving from Europe. Common colonial green manure crops were rye, buckwheat and oats. Traditionally, the incorporation of green manure into the soil is known as the fallow cycle of crop rotation, which was used to allow the soil to regain its fertility after the harvest.

How green manuring improve the fertility of soil

Green manuring is a sustainable agricultural practice that significantly improves the fertility of soil through various mechanisms. Here are detailed explanations of how green manuring enhances soil fertility:

a) ***Nutrient Accumulation and Recycling:*** Green manure crops actively absorb nutrients, including nitrogen, phosphorus, and potassium, from the lower layers of the soil through their root systems. When these crops are ploughed back into the soil as organic matter, they release these nutrients, making them available to subsequent crops. This nutrient recycling helps maintain soil fertility by ensuring that essential elements are continuously cycled within the ecosystem.

b) ***Nutrient Retention:*** Green manure crops, with their dense root systems, help prevent the leaching of nutrients from the soil. Leaching occurs when rainfall or irrigation water carries nutrients downward into deeper soil layers or groundwater, making them unavailable to plants. Green manure crops act as a barrier, reducing nutrient loss and ensuring that valuable nutrients remain in the upper soil profile where plants can access them.

c) **Nitrogen Fixation:** Many green manure crops, particularly legumes, have a symbiotic relationship with nitrogen-fixing bacteria called rhizobia. These bacteria reside in the root nodules of legumes and have the remarkable ability to convert atmospheric nitrogen gas (N_2) into ammonia (NH_3) and other nitrogen compounds that plants can use for growth. This biological nitrogen fixation not only provides a direct source of nitrogen for the green manure crop but also enriches the soil with nitrogen when the crop is incorporated, benefiting subsequent crops.

d) **Increased Nutrient Solubility:** Green manure crops, as well as the organic matter they add to the soil, promote the activity of soil microorganisms. These microorganisms break down organic matter and produce organic acids during decomposition. These organic acids enhance the solubility of essential nutrients such as lime, phosphate, and various trace elements. As a result, these nutrients become more accessible to plants, supporting their growth and overall health.

e) ***Improved Soil Structure:*** The addition of green manure to the soil enhances its physical properties. The organic matter from green manure helps create better soil structure, increasing its water-holding capacity, aeration, and overall tilth. Improved soil structure allows plant roots to penetrate more easily, access nutrients, and grows more vigorously.

f) Green manuring is a multifaceted approach to improving soil fertility. It enriches the soil with nutrients, prevents nutrient loss through leaching, harnesses nitrogen-fixing bacteria, and enhances nutrient solubility while also benefiting soil structure. This sustainable practice not only boosts crop productivity but also promotes long-term soil health and reduces the need for synthetic fertilizers and chemical inputs, making it an essential component of sustainable and environmentally friendly agriculture.

Classification of green manuring

1. Based on Collection

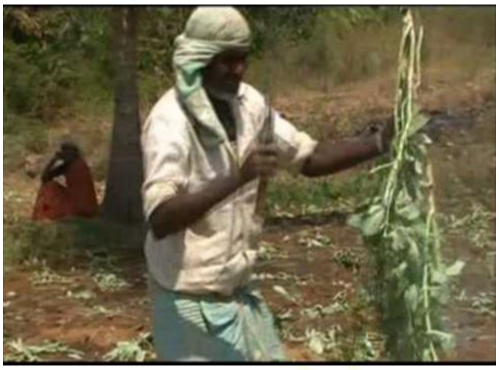
A. ***In-situ green manuring:*** In this system the short duration legume crops are grown and buried in the same site when they attain the age of 60-80 days after sowing. This system of on-site nutrient resource generation is most prevalent in northern and southern parts of India where rice is the major crop in the existing cropping systems [4]. E.g., Sun hemp, Dhaicha, Shervi, Urd, Mung, Cowpea, Berseem, etc.

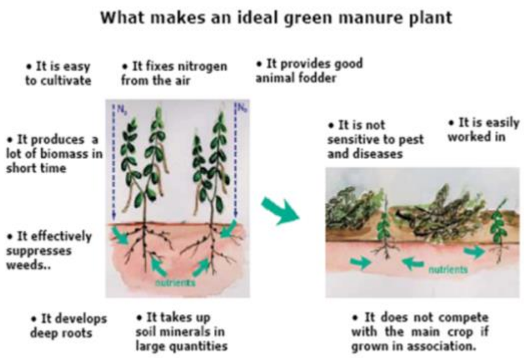

Common legume crops for in-situ green manuring

S. No.	Common name	Botanical name	Growing season
1.	Dhaincha	*Sesbania aculeata*	Zaid/Kharif
		Sesbania rostrata	Zaid/Kharif
2.	Sunhemp	*Crotalaria juncea*	Zaid/Kharif
3.	Mung	*Vigna radiata*	Zaid/Kharif
4.	Cowpea	*Vigna unguiculata*	Kharif
5.	Guar	*Cyamopsis tetragonoloba*	Kharif
6.	Senji	*Melilotus alba*	Rabi
7.	Berseem	*Trifolium alexandrium*	Rabi
8.	Khesari	*Lathyrus sativus*	Rabi

[Source : Singh *et al.*][4]

B. *Green leaf manuring:* Green leaves and tender plant parts of the plants are collected from shrubs and trees growing on bunds, degraded lands or nearby forest and they are turned down or mixed into the soil 15-30 days before sowing of the Crops depending on the tenderness of the foliage or plant parts [5]. E.g., Gliricidia, Pongamia, Neem, Gulmohur, Peltophorum, Calotropis, Avise, Subabul, Wild Indigo, Mahua, *etc*.





2. Based on their Function

Types	Function	Examples
Cover crops	Prevent erosion	Oats, Winter rye, Sinus pea, Lentil, Clover, Cowpea etc.
Break crops	Interrupt the lifecycle of pests and diseases	Mustard, Rye, Brassica, Alfalfa etc.
Leguminous crops(N-fixer)	Enrich soils of available nitrogen	Clover, lupines, vetches. Alfalfa, peas, Beans, soybean *etc*
Nutrient conserving crops	Minimize nutrient leaching and further enrich soil with nutrients addition	Oil radish, Red clover, buckwheat, rye grass etc.

Smother crops	Smother weeds by outcompeting them in growth	Buckwheat, Oil radish, Winter rye, yellow sweet clover etc.

Time interval between burial of GM sowing of next crop

Knowledge of time interval between burial of GM crops and sowing of next food crop for just to facilitate the complete decomposition of the turned in green matter is essential. Ghose *et al.* [6] reported that the time interval was not so important when succulent green manure crop of eight weeks age was buried because transplanting of paddy immediately after burying of green manure crop was as good as any other treatment. But it was necessary to give time interval of 4-6 weeks before planting paddy when the GM was 12 weeks of age.

Techniques for good benefits from Green Manure Crops

The maximum benefit from green manuring can be obtained through better knowledge of suitable sowing time of GM crops. Age or stage of GM crop for burial. Time interval between burial and sowings of next crop.

Nutrient potential of green manures

Green manure	Biomass (tonnes)	N accumulobase (kg/ha)
Sesbania aculeata	22.50	145.00
Sesbania rostrata,	20.06	146.00
Crotalaria juncea,	18.40	113.00
Tephrosia perpurea	6.80	6.00
Green gram	6.50	60.20
Black gram	5.12	51.20
Cowpea	7.17	63.30

Nutrient compositions of common green manures

S. No.	Crop/Weed	Nutrient content						
		Major nutrients (%)*			Total micro nutrients (mg/kg)**			
		N	P_2O_5	K_2O	Zn	Fe	Cu	Mn
1.	*Sesbania rostrata*	2.62	0.37	1.25	40	1968	36	210
2.	*Sesbania speciosa*	3.98	0.24	1.30	50	480	44	110
3.	*Crotalaria juncea*	2.86	0.34	1.27	30	1190	24	110
4.	*Eichhornia crassipes*	2.83	0.93	1.79	50	470	19	420
5.	*Trianthema* Spp.	2.34	0.30	1.15	30	1992	19	200
6.	*Parthenium hysterophorus*	2.66	0.8	1.29	70	470	19	160
7.	*Glyricidia maculeata*	3.49	0.22	1.30	30	550	19	150
8.	*Cowpea residue*	1.70	0.28	1.25	-	-	-	-

9.	*Mungbean residue*	2.21	0.26	1.26	-	-	-	-
[*Source:* *Singh *et al.* [4] and Savitri *et al.* [7]]								

Advantage of green manuring

a) ***Increased Organic Matter:*** Green manure, typically composed of plant residues, adds organic matter to the soil. As these residues decompose, they provide a continuous source of organic material that enriches the soil. This organic matter stimulates the activity of beneficial soil microorganisms, fostering nutrient cycling and soil health.

b) ***Improved Soil Structure:*** Green manures play a crucial role in improving soil structure. The root systems of green manure crops help break up compacted soil, creating channels for air and water movement. This enhances soil aeration, drainage, and tilth, ultimately improving the water-holding capacity (WHC) of the soil. The enhanced structure also reduces runoff and erosion caused by heavy rainfall, leading to better soil conservation.

c) ***Nutrient Cycling:*** Green manure crops have the ability to access nutrients from deeper soil layers and accumulate them in their biomass. When the green manure is incorporated into the upper soil layer, these nutrients become available for subsequent crops. This nutrient cycling process reduces the risk of nutrient leaching and makes essential elements more accessible to plants.

d) ***Nitrogen Fixation:*** Many green manure crops, particularly leguminous ones, have the unique ability to fix atmospheric nitrogen through symbiotic relationships with nitrogen-fixing bacteria in their root nodules. This biological nitrogen fixation process converts atmospheric N_2 into ammonium (NH_4^+), which enriches the soil with readily available nitrogen. This added nitrogen can be used by succeeding crops, reducing the need for synthetic nitrogen fertilizers and promoting sustainable nutrient management.

e) ***Increased Nutrient Availability:*** Green manuring can increase the availability of certain plant nutrients, such as phosphorus (P_2O_5), calcium (Ca), magnesium (Mg), and iron (Fe). The organic matter provided by green manures serves as a nutrient reservoir, gradually releasing these essential elements for plant uptake.

f) ***Synergy with Phosphatic Fertilizers:*** Applying phosphatic fertilizers to green manure crops, especially leguminous ones, can have a synergistic effect on crop yield. The nitrogen-fixing abilities of legumes complement the phosphorus uptake, leading to improved phosphorus availability for the subsequent crop. This combination can result in increased crop productivity.

Function of Green Manuring

a) Green manures such as clover and vetch contain nitrogen fixing symbiotic bacteria in root nodules that fix atmospheric nitrogen in a form that plants can use. This performs the vital function of fertilization. If desired, animal manures may also be added.

b) Depending on the species of cover crop grown, the amount of nitrogen released into the soil lies between 40 and 200 pounds per acre. With green manure use, the amount of nitrogen that is available to the succeeding crop is usually in the range of 40-60% of the total amount of nitrogen that is contained within the green manure crop.

c) Green manure acts mainly as soil-acidifying matter to decrease the alkalinity/pH of alkali soil by generating humic acid and acetic acid.

d) Incorporation of cover crops into the soil allows the nutrients held within the green manure to be released and made available to the succeeding crops. This results immediately from an increase in abundance of soil microorganisms from the degradation of plant material that aid in the decomposition of this fresh material.

e) This additional decomposition also allows for the re-incorporation of nutrients that are found in the soil in a particular form such as nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and sulfur (S).

f) ***Nitrogen fixation:*** The main benefit of using a legume as a green manure is that legumes fix nitrogen from the atmosphere and convert it into a form that is available to other plants. Legumes from a symbiotic association with soil bacteria called rhizobium. These bacteria colonize the root hairs of the legumes and multiply causing swellings, which become nodules. The bacteria benefit from the relationship by obtaining carbohydrates (plant sugars) from the legume. The growing legume benefits from the nitrogen that is captured from the air and converted into ammonium legume benefits from the nitrogen that is captured from the air and converted into ammonium within the nodules.

Research Findings

The effect of green manuring on soil productivity, fertility, structure, erosion prevention, and sustainability is a critical aspect of sustainable agriculture. Green manures, also known as cover crops, play a pivotal role in enhancing soil health and overall agricultural sustainability. Below, we delve into these effects in more detail, referencing scientific studies and agricultural practices:

a) ***Soil Productivity:*** Green manuring, when practiced with crops like *Sesbania rostrata* and *Crotalaria juncea*, significantly improves soil productivity. These leguminous cover crops contribute organic matter, which enhances soil structure and nutrient content. A study conducted by Yadav demonstrated that green manuring with Sesbania rostrata led to an increase in soil organic carbon content, soil moisture retention, and soil aggregation, ultimately resulting in improved soil productivity.

b) ***Soil Fertility:*** Green manures play a vital role in soil fertility by recycling nutrients and preventing nutrient leaching. Leguminous cover crops, in particular, fix atmospheric nitrogen into the soil. A study by Drinkwater *et al.* [8] found that leguminous green manure crops contributed significantly to soil nitrogen availability, benefiting subsequent crops and reducing the need for synthetic nitrogen fertilizers.

c) ***Improved Soil Structure:*** Green manures help improve soil structure by enhancing soil aeration and drainage. They add organic matter that encourages the development of stable soil aggregates. Research by Amoah *et al.* [9] demonstrated that green manuring with various cover crops improved soil structure and reduced bulk density, leading to better water infiltration and root penetration.

d) ***Prevention of Soil Erosion:*** The root systems of green manure crops penetrate the soil, anchoring it and preventing erosion caused by wind and rain. A study by Blanco-Canqui *et al.* [10] found that cover cropping significantly reduced soil erosion rates, making it an effective erosion control strategy.

e) ***Sustainability:*** Green manures contribute to agricultural sustainability by providing various benefits without substantial additional costs. Small-scale farmers can integrate green manures into their cropping systems, reducing the need for chemical inputs. This approach aligns with sustainable agricultural practices.

f) ***Green Manures as Mulch:*** Green manure plants can be used as mulch, which has several advantages:

- **Weed Control:** Mulching helps suppress weed growth, reducing competition with crops.
- **Erosion Protection:** Mulch cover protects the soil from erosion caused by wind and water.
- **Moisture Conservation:** Mulch reduces evaporation, keeping the soil moist and conserving water resources.

Conclusion

Green manuring is a promising and sustainable approach to enhance soil health and fertility in agriculture. This eco-friendly practice reduces reliance on synthetic fertilizers, enriching the soil with organic matter and nutrients, leading to increased crop yields and improved quality. It also fosters diverse microorganisms, aiding nutrient availability and disease control while preventing soil erosion and improving water retention. Additionally, it contributes to carbon sequestration, helping combat climate change. Successful adoption requires regional and crop-specific considerations and support systems. Green manuring is crucial for sustainable agriculture and addressing global environmental challenges, promoting a healthier planet for future generations. Scientific research and practical experience have shown that incorporating green manure crops into agricultural systems can lead to improved soil productivity, structure, and erosion control while reducing the reliance on synthetic fertilizers and herbicides, making it a sustainable choice for farmers.

References

1. Meena, B. L., Fagodiya, R. K., Prajapat, K., Dotaniya, M. L., Kaledhonkar, M. J., Sharma, P. C., and Kumar, S. 2018. Legume green manuring: an option for soil sustainability. *Legumes for soil health and sustainable management* 387-408. [google scholar] [DOI]
2. Das, K., Biswakarma, N., Zhiipao, R., Kumar, A., Ghasal, P. C., and Pooniya, V. 2020. Significance and management of green manures. *Soil Health* 197-217. [google scholar] [DOI]
3. Maitra, S., Zaman, A., Mandal, T. K., and Palai, J. B. 2018. Green manures in agriculture: A review. *Journal of Pharmacognosy and Phytochemistry* 7(5):1319-1327. [google scholar] [DOI]
4. Singh, V., Singh, B. and Khind, C.S. 1992. Nutrient transformations in soil amended with green manures. *Adv. Soil. Sci*. 20: 238-298. [google scholar] [DOI]
5. Rani, T. S., Umareddy, R., Ramulu, C., and Kumar, T. S. 2021. Green Manurs and Grean leaf manures for soil fertility improvement: A review. *Journal of Pharmacognosy and Phytochemistry* 10(5):190-196. [google scholar] [DOI]
6. Ghosh, R.L.M., Ghate, M.B. and Subrahmanyam, T. 1960. Rice in India. ICAR New Delhi-12.
7. Savithri, P., Poongothai, S., Joseph, B and Vennila, R.K. 1999. Non-conventional sources of micronutrients for sustainable soil health and yield of rice-green gram cropping system. *Oryza*, 36 (3): 219-222. [google scholar]
8. Drinkwater, L. E., Wagoner, P., and Sarrantonio, M. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. Nature 396(6708):262-265. [google scholar] [DOI]
9. Blanco-Canqui, H. 2018. Cover crops and water quality. *Agronomy Journal* 110(5):1633-1647. [google scholar] [DOI]
10. Amoah, A.C., Kwiatkowska-Malina, J., Thornton, S. F., Fenton, O., Malina, G., and Szara, E. (2020). Restoration of soil quality using biochar and brown coal waste: A review. *Science of the Total Environment* 722:137852. [google scholar] [DOI]