Introduction

For the past 40 years, chemical fertilisers have been the primary supply of plant nutrients in agriculture. In developing countries such as India, subsidised fertiliser costs encouraged farmers to use more chemical fertilisers for crop productivity. Neglecting organic manures, notably green manures and green leaf manures, in crop cultivation has led to nutritional deficits and a loss in soil productivity and soil health.

To overcome this, green leaf manuring is a low-cost agricultural technology that reduces the need for chemical fertilisers and improves soil fertility and soil health. It also suppresses weeds, root knot nematodes, and diseases.

Green manures, or fertility-building crops, are crops that help the soil. These crops played an important part in agriculture in ancient times. Farmers in India knew the importance of green manuring for thousands of years, according to treatises such as the *Vrikshayurveda*. In the past, farmers would plough down plants like broad beans in ancient Greece. Green manuring has been practiced in China since 1134 B.C. Chinese agricultural texts noted the importance of introducing grasses and weeds for replenishing agricultural soils hundreds of years ago. The Chinese, Greeks, and Romans were aware of its importance at least three thousand years ago.

These historical references clearly highlight that the practice of green manuring and the understanding of its benefits were well established among ancient civilizations.

Green Manuring and Green Leaf Manuring

Green manuring can be defined as the practice of ploughing or turning into the soil undecomposed fresh green plant tissue for the purpose of improving the fertility status, and the physical and biological condition of the soil. Raising certain crops followed by incorporation in-situ is known as green manuring. The seeds of such crops are usually broadcast into the fields, grown to 50% flowering stage (45–60 days depending on the crop), and then ploughed and incorporated into the soil.

Green leaf manuring differs slightly from green manuring. It involves cutting down and incorporating the branches, twigs, leaves, bushes, shrubs, etc., raised on field bunds, vacant patches, wastelands, and nearby forest areas. In agriculture, it is mostly practiced in paddy fields. The major difference is that green

manure is cultivated along with the crop and incorporated into the soil, whereas in the case of green leaf manure, it is collected from the field or outside the field.

In both green manure and green leaf manure, it is not necessary that the crop be leguminous or nitrogen-fixing.

Conventional agricultural practice promotes the use of chemical fertilisers for plant nutrition. The uncontrolled and unscientific use of only chemical fertilisers without any organic manure negatively affects soil productivity, soil health, and soil fauna and flora. The usage of synthetic chemicals has also resulted in environmental pollution and degradation of natural resources, such as eutrophication.

On the contrary, the gradual rise in fertiliser prices in recent years, the necessity to maintain soil health and crop yield under intensive cropping systems, and increased awareness of organic farming and its products have prompted a return to the use of green manure and green leaf manure. They are also thought to inhibit soil-borne plant infections and diseases, while significantly improving soil structure and microbial activity.

The most significant barriers to large-scale implementation of green manuring technology are optimal soil conditions, environment, and biotic stress.

Types of Green Manures

Green Manuring In-Situ

Green manuring crops are grown and buried in the crop field either as a pure crop or as an intercrop with the main crop. It can be further classified into leguminous and non-leguminous crops.

Common leguminous green manuring crops: Dhaincha, Sesbania rostrata, Sunn hemp, Cowpea, Cluster bean, Indigo, Azolla, Green gram, Black gram, Berseem, Lucerne, Alfalfa, Field bean, Crimson/red/white clovers, Lupins, Vetches.

Common non-leguminous green manuring crops: Sunflower, Buckwheat, Rye, Mustard.

Green Leaf Manuring

This involves the collection of leaves and tender twigs from shrubs and trees grown on bunds, wastelands, and nearby forest areas, and incorporating them into cultivable fields.

Common leguminous green leaf manuring crops: Gliricidia, Cassia, *Pongamia glabra*, White gulmohar, Peltophorum, Gulmohur.

Common non-leguminous green leaf manuring crops: Calotropis, Adathoda, Thespesia, Subabul, Neem, *Parthenium hysterophorus, Eichhornia crassipes, Trianthema portulacastrum, Ipomoea, Calotropis gigantea.*

Characteristic Features of Green Manures

Green manure crops should be chosen based on the location's edapho-climatic characteristics, rainfall pattern, irrigation facility, and turnaround time, as well as the duration of the main crop in the field.

Key features include:

- Resistance/tolerance to natural calamities like drought, floods (waterlogging), temperature stress, shade, etc., and biotic stress like insect and pest attack.
- Fast-growing crops with more foliage and ability to cover land quickly.
- High biomass and nutrient accumulation with low lignin content and low C:N ratio.
- High nitrogen accumulation in underground plant parts.
- Preferably legume in nature, fixing atmospheric nitrogen to improve soil fertility.
- Low cost of production.
- Ability to grow in all agro-climatic zones with less water, ensuring high water use efficiency.
- Multiple uses (fodder, green manure, N fixation, shade, cover crop, erosion control, etc.).

- High seed production and viability.
- Easy incorporation, decomposition, and timely nutrient release.
- Responsive to bio-inoculation such as rhizobium.

Features of green leaf manure crops:

- Moderate tall shrubs or trees for easy cutting.
- Insecticidal properties.
- Resistance/tolerance to natural calamities and pests.
- Ability to regrow quickly after harvesting.
- Multiple uses (fodder, green manure, shade, cover crop, erosion control, etc.).
- Suitability across varied climatic conditions.

Green manuring crops (in situ)

Green Manuring Crops (In-Situ)

Dhaincha (*Sesbania aculeata*)

Dhaincha is a fast-growing, succulent, root-nodulating legume valued for its rapid biomass build-up and rich nitrogen content, making it one of the most effective green manures. It decomposes easily and can be incorporated 8–10 weeks after sowing. This crop adapts to many soil and climate conditions.

- **Seed rate:** 20–25 kg/ha

- **Green matter yield:** 10–20 t/ha
- **Nitrogen fixation:** 75–80 kg/ha
- **Nutrient composition:** 3.50% N, 0.60% P_2O_5, 1.20% K_2O

It is tolerant to drought, flooding, and saline soil conditions. After decomposition, it contributes humus, enhances aeration, lowers the C:N ratio, improves microbial activity, and suppresses soil pests. Due to its multifunctionality, it also serves as fodder, shade, and windbreak, while improving soil fertility in rice and rainfed systems.

Sesbania speciosa

Sesbania speciosa produces approximately 16–17 t/ha of green biomass.

- **Seed rate:** 15 kg/ha
- **Nitrogen fixation:** 80–110 kg/ha
- **Nutrient composition (dry weight):** 2.71% N, 0.53% P_2O_5, 2.21% K_2O

It resembles Dhaincha and is commonly grown before rice or other rainfed crops. It can also be cultivated in standing water or along rice bunds. Its biomass production is higher than *Sesbania aculeata*.

Sesbania rostrata

Sesbania rostrata is a semi-aquatic legume that forms nodules on both stems and roots, making it especially suited for waterlogged rice fields.

- **Seed rate:** 30–40 kg/ha

- **Green matter yield:** 15–20 t/ha
- **Nitrogen fixation:** 150–180 kg/ha

Seeds require scarification (sulphuric acid treatment for 15 minutes) to achieve uniform germination. It is suitable for summer season cultivation and as an intercrop with rice.

Sunn hemp (*Crotalaria juncea*)

Sunn hemp is a vigorous, fast-growing crop that establishes quickly under warm, dry soil conditions, forming a dense canopy that suppresses weeds and nematodes.

- **Seed rate:** 25–35 kg/ha
- **Green biomass yield:** 13–20 t/ha (in 10 weeks)
- **Nitrogen fixation:** 50–80 kg/ha
- **Nutrient composition:** 2.30% N, 0.50% P_2O_5, 1.80% K_2O

It is ideal before rice, sugarcane, or rainfed crops. Some varieties contain toxic alkaloids, requiring caution if used as forage. Susceptible to waterlogging.

Cowpea (*Vigna unguiculata*)

Cowpea is a highly productive, heat-tolerant annual legume used as grain, fodder, and green manure.

- **Seed rate:** 35–40 kg/ha
- **Green biomass yield:** 9–10 t/ha

- **Nitrogen fixation:** 140–150 kg/ha

It is sensitive to waterlogging and best grown in well-drained soils. It is commonly used as a preceding crop for rice in Kerala.

Greengram (*Vigna radiata*)

Greengram, or mung bean, is a dual-purpose crop for seed and green manure.

- **Seed rate:** 30 kg/ha
- **Green biomass yield:** 3.5–4 t/ha
- **Nitrogen fixation:** 38–50 kg/ha

It is typically incorporated 35–40 days after sowing and fits well into crop rotations with rice.

Black gram (*Vigna mungo*)

Black gram, or curd bean, is another dual-purpose crop.

- **Seed rate:** 30 kg/ha
- **Green biomass yield:** 3.5–4 t/ha
- **Nitrogen fixation:** 30–36 kg/ha

It is incorporated 35–40 days after sowing, usually before rice.

Groundnut (*Arachis hypogea*)

Groundnut is cultivated as a cover crop, intercrop, and green manure. It improves soil fertility through nitrogen fixation and has a lower C:N ratio compared to sunn hemp, making it decompose faster. Groundnut contributes more nitrogen to the succeeding crop than sunn hemp.

Kolingi / Wild Indigo (*Tephrosia purpurea*)

This slow-growing, drought-tolerant crop is suited for sandy soils but not waterlogging.

- **Seed rate:** 20–25 kg/ha
- **Green matter yield:** 8–10 t/ha

Seeds germinate slowly due to a waxy coat but can be treated by soaking in hot water (55ºC for 2–3 minutes). Volunteer plants often emerge if grown for consecutive seasons.

Mustard (*Brassica juncea)*

Mustard Mustard is a fast-growing non-leguminous green manure crop that suppresses weeds and improves soil structure. Its deep roots help recycle nutrients from the subsoil and add organic matter when incorporated.

- **Seed rate:** 5–7 kg/ha
- **Green matter yield:** 8–10 t/ha (in 45–60 days)

It is best incorporated at the flowering stage for maximum biomass and nutrient return.

Indigo (*Indigofera tinctoria*)

A long-duration crop resembling Kolingi but leafier, also valued as a medicinal plant.

- **Seed rate:** 20 kg/ha
- **Green matter yield:** 8–10 t/ha

Performs well in clayey soils with irrigation.

Berseem (*Trifolium alexandrinum*)

A multi-cut leguminous fodder crop, also effective as green manure.

- **Seed rate:** 20–25 kg/ha

It is moderately salt-tolerant and useful for reclaiming saline soils, often grown in paddy–berseem rotations.

Cluster bean (*Cyamopsis tetragonoloba*)

A drought-tolerant annual legume used for fodder, grain, and green manure.

- **Seed rate:** 40 kg/ha
- **Nitrogen fixation:** ~30 kg/ha

It is often planted before rice and other rainfed crops, and is suitable for cooler regions.

Lucerne (*Medicago sativa*)

Also called “the queen of fodder crops,” lucerne has deep roots that break up soil pans and extract sub-surface nutrients.

- **Seed rate:** 15–20 kg/ha

It is also widely used as livestock feed.

Azolla (*Azolla pinnata*)

Azolla is a nitrogen-fixing water fern, especially used in rice ecosystems.

- **Seed rate:** 50–90 kg/ha
- **Biomass yield:** 8–10 t/ha (in 8–10 days)
- **Nitrogen fixation:** ~52 kg/ha

It also suppresses weeds in rice fields.

Green leaf manuring Crops

Gliricidia (*Gliricidia maculata*)

Gliricidia is a hardy shrub or small tree often planted along bunds and borders. It responds well to repeated pruning and produces a steady supply of leafy biomass within two years. Its foliage decomposes quickly, making it especially suited for incorporation in rice fields.

- Yield: 5–10 kg green leaves/plant/year
- Nutrient content: 2.76% N, 0.28% P_2O_5, 4.60% K_2O

Subabul (*Leucaena leucocephala*)

Subabul is a fast-growing, deep-rooted shrub that fixes large amounts of nitrogen. It thrives in bunds and degraded soils, though it cannot tolerate waterlogging. With proper pruning, it provides abundant biomass and helps boost soil fertility.

- Nitrogen fixation: 500–600 kg N/ha/year

- Nutrient content: 3.5–3.7% N in leaves

Cassia (*Cassia auriculata*)

Cassia is a hardy, drought-tolerant shrub valued in dryland areas where other organic sources are limited. Farmers lop its branches during the flowering stage and incorporate them into fields to improve soil fertility.

- Nutrient content: 1.4–1.6% N in leaves

Neem (*Azadirachta indica*)

Neem is a widely known evergreen tree with pesticidal properties. It is pruned once or twice a year, and its leaves decompose slowly, releasing nutrients steadily. Neem foliage also helps suppress soil pests and diseases.

- Yield: 150–200 kg leaves/tree/year

- Nutrient content: 1.0–1.2% N

White Gulmohur (*Delonix elata*)

White Gulmohur, also called Vadanarayan, is an evergreen tree common in dry regions. Apart from its medicinal uses, it provides a reliable source of green manure leaves year-round.

Gulmohur (*Delonix regia*)

Gulmohur, famous for its red flowers, also provides foliage that farmers collect from bunds and wastelands. The leaves are commonly incorporated into rice fields.

- Nutrient content: 2.76% N, 0.46% P_2O_5, 0.50% K_2O

Peltophorum (*Peltophorum ferrugineum*)

Locally known as Charakonna, Peltophorum is a leguminous tree that grows fast and provides good biomass for green manuring.

- Nutrient content: 2.63% N, 0.37% P_2O_5, 0.50% K_2O

Ipomoea spp.

Ipomoea, or morning glory, is a semi-aquatic creeper that grows rapidly in moist conditions. It spreads quickly, making it a low-cost option for generating biomass in paddy ecosystems.

- Yield: 5–7 kg green matter/harvest, 2–3 harvests/year

- Nutrient content: 2.01% N, 0.33% P_2O_5, 0.40% K_2O

Calotropis (*Calotropis gigantea*)

Calotropis is a wild shrub commonly found on bunds and wastelands. Despite its toxic latex, its leafy biomass is used in manuring systems where other green manure resources are scarce.

- Nutrient content: 2.06% N, 0.54% P_2O_5, 0.31% K_2O

Merits of green manuring

· Huge quantity of Organic matter is added to the soil. Improve soil organic matter and surface nutrient concentration (especially available nitrogen), while reducing losses through leaching and erosion.

. Enhances soil aggregation and water-holding capacity and improves physical attributes like infiltration and aeration.

· The nitrogen fertilizer equivalence (NFE) of green manures ranges from 50 to 100 kg N/ha for green manure grown for 45–60 days. One legume crop can substitute for applying 30–80 kg N/ha in rice systems. Subsequent research (AICRP-IFS) suggests that up to 50% of fertilizer N needs in various cropping systems can be substituted via green manuring without yield loss.

· Approximately 40–60% of the total nitrogen in the green manure crop becomes available to subsequent crops.

. Reduces dependency on chemical fertilisers and mitigates their harmful effects.

· Increases supply of macro and micronutrients through recycling and fixation.

· Improves microbial activity and supports beneficial soil organisms.

· Suppresses weed growth, pests, and some soil-borne diseases.

· No adverse impact on soil and environment, hence environment friendly and help in maintaining the fertility of the soil in long term

· Provide habitat for predatory beneficial insects, reducing pesticide requirements.

· Deep-rooted green manure crops bring nutrients from deeper layers to benefit shallow-rooted crops.

· Regulates soil temperature and moisture, creating a better microclimate.

· Provides supplementary animal fodder

· Reducing leaching losses

· Suppressing weed growth in critical period of crop weed competition

- Reducing pest and disease problems enhancing the microclimate in the soil

Successful Green Manuring: Key Practices

There are some important Points to keep in mind for successful and efficient green manuring.

Blending with usual farming practice

It should be blend smoothly into your usual farming routine**.** Green manure should support rather than disrupt your main crops. In regions with very little rain, where dry farming is the norm, green manuring may not be practical because there's just not enough moisture in the soil.

Time of sowing

The timing of sowing makes a big difference in results. Green manure is usually planted right after the monsoon, when soil moisture is high. If irrigation is available, fast-growing crops such as sun hemp or dhaincha can be sown earlier in March–April and incorporated before the main cropping season in May–June. In some cases, they can even be grown alongside the main crop to save time and land preparation.

Time of incorporation

Green manure crops should be incorporated into the soil while still young and succulent, usually at the flowering stage. At this point, they contain high levels of nitrogen, protein, and water-soluble nutrients. Because the plants are soft and have a low carbon-to-nitrogen ratio, they decompose quickly, releasing nutrients efficiently for the next crop

Depth and type of incorporation

Avoid burying the green manure too deeply, deep burial can push nutrients beyond reach of the next crop’s roots. Instead, till it into a suitable, shallow depth. Immature plants can decompose effectively at any depth, but mature ones should only be buried shallowly. In dry conditions, adding water ensures proper decomposition.

Time interval

Decomposition speed depends on the type of crop and the weather. Soft, leafy plants break down quickly, while woody or fibrous ones take longer. Generally, decomposition takes 4–6 weeks, so it is advisable to wait 35–40 days after incorporation before planting the next crop. This ensures that nutrients are available and the soil is in the best condition for healthy growth.

Conclusion

Green manuring is a low-cost, eco-friendly practice that improves soil health and sustainability. It enhances organic matter, fertility, and soil biology, while reducing erosion, weeds, and chemical dependency. Leguminous green manures add extra nitrogen by fixing it from the air, boosting the growth of subsequent crops.

By blending traditional knowledge with modern farming, green manuring and green leaf manuring can play a vital role in sustainable agriculture, protecting soil productivity for the long term.

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