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Green Manure Crops: A Review

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ABSTRACT: Injudicious use of synthetic chemical fertilizers without proper replenishment of soil organic matter and fertility are posing threat to soil and crop productivity. Further, indiscriminate use of synthetic pesticides and growth regulators contaminated the soil, water and air, thus affected the ecosystem services and ecological balance. Chemical Agriculture degraded the resource base for future generations thus food and nutritional security are at stake. Among many low monetary input practices to reduce the impact of these ill effects, green manuring is the most important and popular one. The results of research across the globe indicated that incorporation of a leguminous green manure crop can substitute up to 50% of N fertilizer needs of various cropping systems besides improving soil fertility and health. This practice play a pivotal role in promoting organic farming. However, availability of green manure seed, optimum soil moisture and suitable machinery for incorporation are the major challenges faced by the farmers. In this article, we have given an overview of green manuring and green leaf manuring, associated benefits and their role in sustaining the soil health and crop production.

Keywords: Green manures, soil fertility, ecosystem services, contamination.

INTRODUCTION

The importance of green manuring was known to farmers in India many thousands years back according to the treatises like Vrikshayurveda. In yesteryears, the farmers used to plough down the plants like broad bean in Ancient Greece. The practice of green manuring was initiated in China as early as 1134 B.C. Chinese agricultural texts mentioned about the significance of incorporating the grasses and weeds for nourishing the Agricultural soils, hundreds of years back. The importance was known to early North American colonists arrived from Europe who recognized rye, buckwheat and oats as green manure crops (James, 1980). Many years back, raising and *insitu* incorporation of green manure crops as a part of crop rotation to rejuvenate the soil fertility, was very well recognized. In India, the area under green manuring was estimated to be approximately 1.23 M ha only (FAI, 2015) and nearly 80% of the area was reported from six states *viz.*, U.P., A.P., M.P., Karnataka, Orissa, Rajasthan, Punjab and West Bengal. The crops that are grown for the purpose of improving the organic matter content in the soil are called 'Green manure crops'. Raising of certain crops followed by incorporation *in-situ* is known as green manuring. The seeds of such crops are mostly broadcasted in well pulverized Agricultural fields and grown upto 50% flowering stage i.e., 45-60 days depending on the crop and ploughed down into the soil (Fig. 1). Green leaf manuring slightly differs from green manuring. It involves cutting down and incorporation of the branches, twigs, leaves, loppings of trees, bushes, shrubs etc., raised on field bunds, vacant patches, wastelands and nearby forest areas, in the Agricultural fields, mostly rice fields. Green leaf manuring saves land and water, but, non-legumes doesn't fix atmospheric N unlike legumes.

Though green manuring (GM) and (or) green leaf manuring (GLM) used to be followed widely by farmers in yesteryears, but, declined gradually due to intensive Agriculture practices and increased availability of chemical fertilizers at subsidized rates thus usage, with a view to maximize productivity from minimum land (Singh *et al.*, 1991).

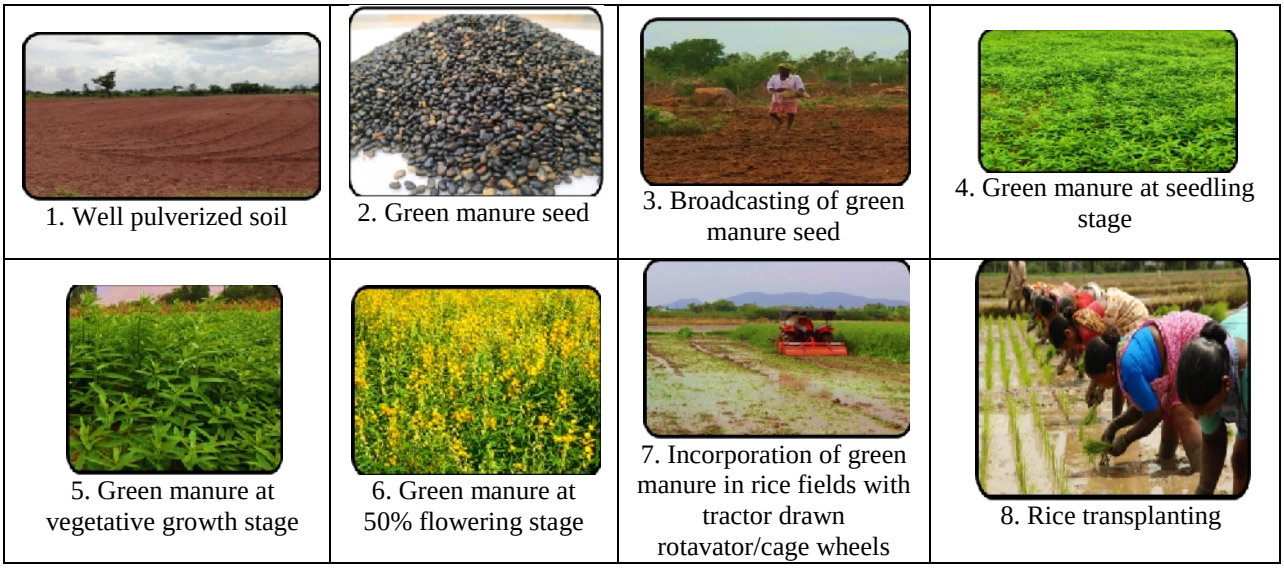

Fig.1. Sequential steps in growing and incorporation of a green manure crop.

This resulted in decrease in soil organic matter, fertility and productivity leading to decline in factor productivity. The usage of synthetic chemicals also resulted in pollution of environment and degradation of natural resource base. On the contrary, gradual increase in the prices of fertilizers in the recent years, need for sustaining soil health and crop productivity under intensive cropping systems and improved awareness on organic farming and its' products are necessitating us to revert back to adoption of GM and GLM. They are believed to suppress the soil borne plant pathogens and diseases (Larkin, 2013) besides bringing out significant improvement in soil structure and microbial activity (Thorup-Kristensen *et al.*, 2003; Grandy *et al.*, 2002, Liu *et al.*, 2010). However, optimum soil, environment and biotic stresses are the major limitations for large scale adoption of green manuring technology.

Characteristic features of plants preferred for green manuring

The green manure crops are generally selected based on the location specific edapho-climatic conditions, rainfall pattern, irrigation facility and turn-around time available (Thimmanna *et al.*, 2014). Following are some of the preferred characteristic features of crops selected for green manure purpose.

For green manure purpose

- Fast growing crops with more foliage and ability to cover the land quickly
- Short duration
- High biomass and nutrient accumulation
- Preferably legume in nature, so that, they fix atmospheric N and improves the soil fertility and supply nutrients to component crops and (or) subsequent crops
- High N sink in underground plant parts
- Low cost of production
- Resistance/tolerance to natural calamities like drought, floods (waterlogging), high or temperature stress, shade etc.,
- Ability to grow in all agro-climatic zones
- Ability to grow with less water thus high water use efficiency
- Multifarious uses (fodder, green manure, N fixation, seed, shade, cover crop, erosion control)
- Insensitive to photo and light periods
- Ability to fit between two main crops
- Ability to come up well in impoverished soils, waste lands etc.,
- High seed production potential
- High seed viability for longer period
- Meagre storage pest problem
- Low lignin content
- Low C:N ratio
- Easy for incorporation and decomposition
- Easy and timely release of nutrients
- Responsive to inoculation
- Resistance or tolerance to pest and diseases

For green leaf manuring purpose

- Moderate tall growing shrubs or tress for easy lopping
- Ability to produce heavy foliage and biomass
- Insecticidal properties
- Legume nature
- Resistant to lopping and ability to regrow faster
- Amenable for quick decomposition
- Multipurpose use (fodder, green manure, N fixation, seed, shade)
- Highly resistant to adverse climatic conditions
- Ability to grow in all agro-climatic zones

Classification of green manures and green leaf manure crops

The available green manure and green leaf manure crops are classified and presented in Fig. 2.

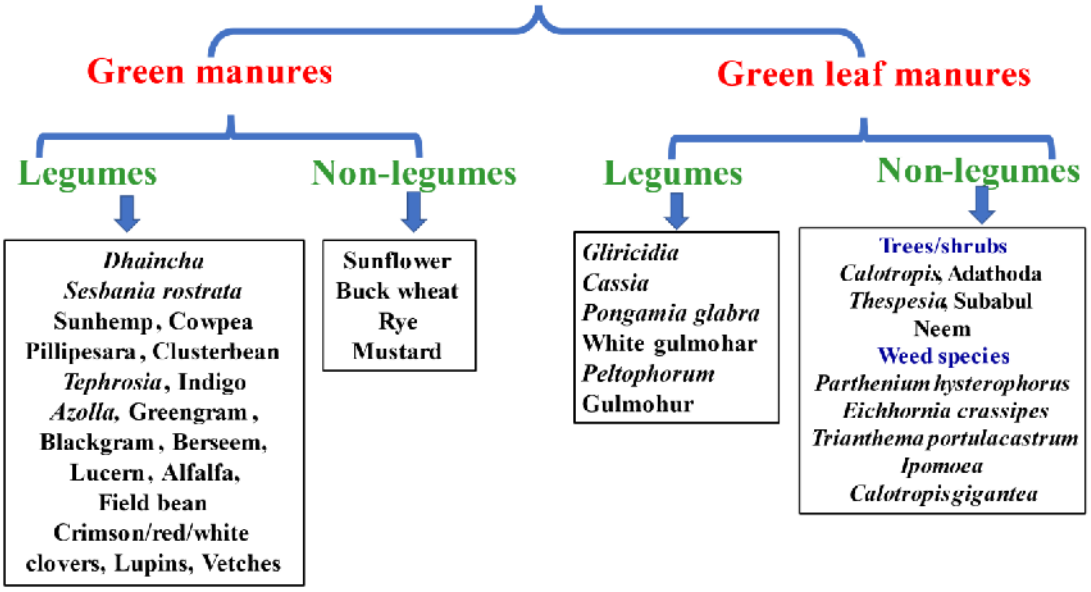

Fig. 2. Classification of green manure crops.

About green manure crops: The details of crops used for green manures and green leaf manures are furnished below based on the literature available (Pandey, 2013; Kumar *et al.*, 2019).

Dhaincha *(Sesbania aculeata/cannabina)*

- Root nodulating legume
- Multipurpose crop (green manure, fodder, shade giving, wind break)
- Commonly cultivated GM crop
- Quick growing GM crop with more number of nodules (Carlsson and Huss-Danell, 2003)
- Seed rate: 50 kg ha^{-1}
- Can be incorporated at 45 days after sowing (DAS)
- Produces green matter @ 15-20 t ha^{-1}
- Fast growing
- Resistant to drought and withstands waterlogging and salinity (Kalidurai, 1988)
- Contains 3.50% N, 0.60% P_2O_5 and 1.20% K_2O
- N fixation: 75-80 kg ha^{-1} (Zaman *et al.*, 1996)
- Suitable for green manuring in rice and rainfed crops
- Insect (leaf webber) menace is a constraint
- Sensitive to photoperiod

Sesbania (*Sesbania speciosa)*

- Resembles *Dhaincha*
- Can be cultivated in the standing water or even on the bunds
- It is more drought tolerant than *S. aculeata* (Patnaik *et al.*, 1957)
- Seed rate @ 35-40 kg ha^{-1}
- Can be incorporated at 45 days after sowing (DAS)
- Produces green matter @ 16-17 t ha^{-1}
- Contains 2.71% N, 0.53% P_2O_5 and 2.21% K_2O
- N fixation: 83-108 kg ha^{-1} (Ndoye *et al.*, 1988)
- Can be grown preceding to rice and rainfed crops

Sesbania (New Dhaincha: Sesbania rostrata)

- It is both stem and root nodulating green manuring crop unlike others
- Thrives well under waterlogged condition
- Not suitable for alkaline soils
- Seed rate 30-40 kg ha^{-1}
- Scarification of seeds with concentrated H_2SO_4 for 15 minutes for quick germination is required
- Produces green matter @ 15-20 t ha^{-1}
- N fixation: 83-108 kg ha^{-1} (Zaman *et al.*, 1996)
- Can be grown as an intercrop along with rice
- Incorporated at 8-10 weeks after sowing

Sunhemp *(Brown hemp/India hemp/Madras hemp: Crotalaria juncea)*

- Quick growing green manure cum fiber crop and can't withstand heavy irrigation or water logging
- Seed rate: 25-35 kg ha^{-1}
- Produces green matter @ 13-15 t ha^{-1}
- N fixation: 50-60 kg ha^{-1} (Sarkar *et al.*, 2015)
- Contains 2.30% N, 0.50% P_2O_5 and 1.80% K_2O
- Less tolerant to acidity, salinity and water logging, but, performs better under low rainfall and moisture conditions (Panse *et al.*, 1965)
- Can be grown preceding to rice and other rainfed crops and is incorporated at 10 weeks after sowing

Wild indigo or kolingi (*Tephrosia purpurea)*

- Slow growing green manure crop

- Not useful for fodder
- Suitable for light soils
- Resists drought but does not withstand water stagnation
- Seed rate: 20-25 kg ha^{-1}
- Produces green matter @ 8-10 t ha^{-1}
- N accumulation: 70-115 kg ha^{-1}

Cowpea *(Vigna unguiculata)*

- Most productive heat adapted annual legume
- Can be used as grain/green manure crop, for animal fodder and also as a vegetable
- Very sensitive to waterlogging (Morris *et al.*, 1986).
- Seed rate: 35-40 kg ha^{-1}
- Produces green matter @ 9-10 t ha^{-1}
- High water use efficiency than *S. aculeata* and clusterbean (Singh *et al.*, l98l).
- N fixation: 140-150 kg ha^{-1} (Ledbetter, 2005)
- Seed rate: 40 kg ha^{-1}
- Contains 1.4-1.5% N
- Can be grown preceding to rice

Pillipesara *(Phaseolus trilobus)*

- Dual propose crop which can produce green fodder and manure
- Slow growing
- Seed rate: 10-15 kg ha^{-1}
- Produces green matter: 8-10 t ha^{-1}
- N fixation: 102 kg ha^{-1} (TNAU, 2020)

Clusterben *(Cyamposis tetragonaloba)*

- Drought tolerant annual legume
- Fodder, grain, green manure and gum purpose
- Preferred under erosion prone area (Palaniappan *et al.*, 1990)
- Seed rate: 40 kg ha^{-1}
- N fixation 30 kg ha^{-1}
- Can be grown preceding to rice and other rainfed crops

Azolla (*Azolla pinnata)*

- N fixing fern and can be used as green manure crop
- Seed rate: 50-90 kg ha^{-1}
- Green matter @ 8-10 t ha^{-1}
- Can be incorporated at 35 DAS
- N fixation: 52 kg ha^{-1} (Bhuvaneshwari and Singh, 2015)
- Can be grown in rice ecosystem
- Can suppress weed growth during initial stages of rice crop growth

Greengram (Mungbean: *Vigna radiata*)

- Dual purpose crop i.e., seed and green manure
- Seed rate: 30 kg ha^{-1}
- Green matter @ 3.5-4.0 t ha^{-1}
- Can be incorporated at 35-40 DAS
- N fixation: 38-50 kg ha^{-1} (Kallimath and Patil, 2018)
- Highly suitable as preceding crop to late planted rice (eg. for Telangana sona variety), for for seed and (or) *insitu* incorporation
- Greengram residue incorporation was proved to be effective like that of *Sesbania* GM in rice–wheat system in India

Blackgram (Urdbean: *Vigna unguigulata*)

- Dual purpose crop i.e., seed and green manure
- Seed rate: 30 kg ha^{-1}
- Green matter @ 3.5-4.0 t ha^{-1}
- Can be incorporated at 35-40 DAS
- N fixation: 30-36 kg ha^{-1} (Singh and Usha, 2002)
- Can be grown preceding to rice crop, for *insitu* incorporation

Wild indigo (*Tephrosia purpurea*)

- Slow growing green manure crop
- Not grazed by the cattle
- Drought tolerant hardy plant
- Susceptible to waterlogging
- Its waxy seeds need treatment with sand or hot water @ 55°C for 2-3 minutes for quick germination
- Seed rate: 20-25 kg ha^{-1}
- Produces green matter @ 8-10 t ha^{-1}

Indigo (*Indigofera tinctoria*)

- It is long duration dual purpose crop i.e. green manure and medicinal plant
- Resembles wild indigo but more leafy
- Suitable for heavy clay soils
- Resistant to drought
- Seed rate: 20 kg ha^{-1}
- Produces green matter @ 8-10 t ha^{-1}

Berseem (Trifolium alexandrianum)

- Popular as multi cut *rabi* leguminous fodder crop. The last cut is not used for fodder, but, it can be used as green manure crop
- Possess moderate tolerance for salinity and can be used for the reclamation of saline soils. Paddy-berseem rotation is good for saline soils
- Seed rate: 20-25 kg ha^{-1}

***Lucern (Medicago sativa* L.)**

- It is a very deep rooted green manure with vigorous roots that can draw nutrients from sub-surface layers and break soil pans.
- Seed rate: 15-20 kg ha^{-1}

Sweet clover, Berseem clover, Crimson clover, Milk vetch, Hairy vetch are other minor green manure crops that produces biomass and releases N into the soil.

About green leaf manure crops

Glyricidia *(Glyricidia maculata)*

- It is a shrub and useful for green leaf manuring
- Popular for shade and green leaf manure in tea, coffee and cocoa plantations
- Can be grown on bunds and also as a border crop

- Suitable for alley cropping
- Will not affect the performance of field crops due to it's shade
- The plants will be ready for pruning in two years after planting
- Pruning can be done at a height of 2-3 m height for 2-3 times every year
- Each plant gives 5-10 kg of green leaves annually
- Contains 2.76% N, 0.28% P_2O_5, 4.60% K_2O
- Can be incorporated in rice fields well ahead of planting
- Propagates by planting stem cuttings or seedlings

Pongamia *(Pongamia glabra)*

- It is a leguminous moderate sized ever green tree
- It can be grown successfully on roadsides, river banks, tank bunds, in coastal forests, along streams and wastelands
- Two to three months old seedlings can be planted at 4 to 5 m apart to establish and maintain a *pongamia* garden
- Lopping may be taken once or twice a year and a tree gives on an average 100 to 150 kg of green material per lopping which can be incorporated in the wet lands well ahead of rice plantings
- N content in green leaf manure: 1.3-1.5%

Subabul *(Leucaena leucocephala)*

- It is a leguminous branched shrub
- Dual purpose crop i.e. green leaf manure and forage
- Can be grown on bunds, borders and waste lands
- Can't tolerate flooding
- Needs aggressive lopping to avoid shading effect
- Leaves contain 3.5-3.7% N
- Fixes 500-600 kg N ha^{-1} $year^{-1}$
- Can be incorporated in rice fields well ahead of planting

Neem (*Azadirachta indica*)

- It is a large ever green avenue tree with profuse branching and plenty of green foliage
- Can grow on all types of soils
- They can be grown along field borders, rivers banks, roads, waste lands and also in garden lands and homestead gardens
- Trees are established by planting seedlings at a spacing of 5-6 m
- One or two lopping in a year can be taken and each lopping weigh about 150 to 200 kg of green matter
- N content in green leaf manure: 1.0-1.2%

Vadanarayan (White gulmohar: *Delonix elata*)

- It is tropical ever-green tree which can grow on all types of soils
- Possess medicinal value
- It is propagated by stem cuttings
- Two or three loppings can be taken in an year

Cassia (*Cassia auriculata*)

- Its stems and branches can be lopped at flowering stage and used for green leaf manuring
- Drought tolerant
- N content in green leaf manure: 1.4-1.6%

Peltophorum *(Peltoforum ferrugenum:* 2.63% N, 0.37% P_2O_5, 0.50% K_2O)

Gulmohur *(Delonix regia:* 2.76% N, 0.46% P_2O_5, 0.50% K_2O)

About weeds as green leaf manure crops (Pandey, 2013)

***Ipomoea* spp**.

- It is a water loving aquatic shrub
- Spreads through water
- It is quick growing shrub with profuse branching
- It is propagated through plant material and seeds
- It produces abundant green leafy material with in short time
- Can be multiplied by mature stem cuttings
- Two to three lopping can be taken in an year
- Each plant will give 5 to 7 kg of green matter per lopping
- Nutrient concentration: 2.01% N, 0.33% P_2O_5, 0.40% K_2O

Calotropis gigantea

- It is a weed present on field bunds and waste lands
- Water loving aquatic weed
- Abundant along canal bunds
- It is propagated through seeds
- Nutrient concentration: 2.06 0.54% P_2O_5, 0.31% K_2O

Others

- ***Parthenium hysterophorus*** (2.68% N, 0.68% P_2O_5, 1.45% K_2O)
- ***Eichhornia crassipes*** (3.01% N, 0.90% P_2O_5, 0.15% K_2O)
- ***Trianthema portulacastrum*** (2.64% N, 0.43% P_2O_5, 1.30% K_2O)
- ***Cassia fistula*** (1.60% N, 0.24% P_2O_5, 1.20% K_2O)

Miscellaneous species used for green leaf manuring crops/tress in different parts of the country:

Thespesia, Morianga oleflorea, Agave sisalana, Thesphesia populanea, Cassia siamea, Vitex negundo, Bauhina vahii, Lentil, *Pisum sativum, Chrysopogon, Musa sapietum, Quercus leucotrichophora/semicarpifolia, Daphiniphyllum himalayaense, Bridelia retusa, Nyctanthes arbortristis (lesser Himalayalan regiona), Artocarpus* spp., *Adina cardifolia, Terminalia paniculata, Pterocarpus marsupium, Syzgium cumini, Terminalia bellerica, Cleistanthes collinus, Glyricidia* spp (West Bengal).

Green manures: Legumes			
 Dhaincha	 Sunhemp	 Cowpea	 Pilli pesara
 Clusterbean	 Tephrosia	 Indigo	 *Azolla*
 Greengram	 Blackgram	 Berseem	 Lucern (Alfalfa)
 Field bean	 Red clover	 Crimson clover	 White clover
 Lupins		 Vetches	

Green manures: Non-legumes			
 Sunflower	 Buck wheat	 Rye	 Mustard

Green leaf manures: Legumes		
		
Gliricidia	***Cassia* spp.**	***Pongamiaglabra***
		
White gulmohur	***Peltophoram***	**Gulmohur**

Green leaf manures: Non-legume		
		
Calotropis	**Adathoda**	**Thespesia**
		
Subabul	**Neem**	***Parthenium hysterophorus***
		
Eichhornia crassipes	***Trianthema portulacstrum***	***Ipomoea***

Benefits of green manure/green leaf manure

- Essential component of organic farming and integrated nutrient management (INM)
- Leguminous GMs improve the soil fertility through BNF (biological N fixation) and biomass addition
- Controls soil and water erosion, maintains the soil and crop productivity thus offers ecological sustainability in the long run
- Acts as soil amendment by reducing the pH and alkalinity through release of humic and acetic acids. *Sesbania* sp. are highly suitable for reclamation purpose (Keating and Fisher, l985; Rao, 1985; Evans and Rotar, 1986).
- Can be used as mulch which inturn regulates soil temperature, moisture and weed growth
- Improves soil organic matter, nutrients concentration at soil surface especially available N and reduces its losses through leaching and soil erosion, improves the soil aggregation and water holding capacity thus physical properties like water infiltration and aeration
- Nearly 40-60% of the total amount of nitrogen present within the green manure crop is expected to be available to the subsequent crops (Preston, 2003).
- The values of the nitrogen fertilizer equivalence (NFE) (quantity of fertilizer N that must be applied to wetland rice in the fallow treatment to attain grain yield equal to that obtained with green manure and no N fertilizer) of different green manure crops range between 50 and 100 kg N ha^{-1} for 45 to 60 days old green manure crops. Roger and Watanabe (1986) reported that incorporating one legume crop is equivalent to applying 30-80 kg fertilizer N ha^{-1} in rice. Further, according to results of AICRP-IFS, it is possible to substitute up to 50% of fertilizer N needs of various cropping systems through GM without affecting the yield (Dwivedi *et al.,* 2017). Similalry, Neelima *et al.,* (2008) and Kumar *et al.,* (2021) reported that 66.6% and 50% N fertilizer, respectively can be substituted through green manuring in rice crop.
- Yield improvement in rice due to green manuring was found to be in the range of 0.1-0.3 t ha^{-1} in low yield rice cultivars Panse *et al.,* (1965) and 0.65-3.1 t ha^{-1} in high yielding rice varieties as reported by Singh *et al.,* (1991) based on literature available.
- The organic acids released during decomposition of green manure helps in solubilization of insoluble phosphate in soil and make it available to plants, thus, reduces the need for P fertilizer addition to the crops (Singh, 1984; Hundal *et al.,* 1987). The P release and availability is greater in acid and sodic soils than calcareous soils. Similalry, availability of K, Ca, Mg (Katyal, 1977, Khind *et al.,* 1987, Nagarajah *et al.,* 1989), Fe (Takkar and Nayyar, 1986) and Mn was increased due to green manuring, but, reduced the Zn. However, Zn availability was found to be increased in sodic soil with pH of 10.2, due to green manuring (Swarup, 1987).
- Minimizes the ill effects of chemical dominated modern intensive Agriculture
- Improve the organic matter, physical, chemical and biological properties of soil
- Reduces weed menace and weed seed multiplication
- Controls root knot nematodes (Mojtahedi *et al*., 1993)
- Attracts pollinating insects during flowering stage
- Deep root system of few green manure crop bring up nutrients to the upper layer and make it available to shallower-rooted crops
- They harbor predatory beneficial insects which inturn reduces the need for use of pesticides
- Enhances soil microbial biomass and activity. Further, GMs can influence the soil microbial populations thus suppress the diseases especially those caused by *Rhizoctonia, Verticillium, Sclerotinia, Phythophthora, Pythium, Aphanomyces and Macrophomina* in different crops and black scurf, common scab and Verticillium wilt in potato (Larkin, 2013). They can also interrupt the life cycle of pests and diseases.
- *Brown manuring*: It involves growing *Sesbania* or other green manure crops in standing cereal crops and killing them by spraying a post emergence herbicide. By this method, the plant residues remain in the field till their residue decompose in the soil. It helps in suppressing the weed growth and addition of organic matter. The foliage sprayed with herbicide turns brown in colour due to loss of chlorophyll, hence, it is called as 'brown manuring' (Tanwar *et al.,* 2010). For eg. *Sesbania* sp. @ 20 kg ha^{-1} is broadcast three days after rice sowing and allowed to grow for 30 days and sprayed with 2,4-D ethyle ester. It supplies upto 35 kg ha^{-1} N and improves the rice yield by 4-5 q ha^{-1}. Further, it also improves the soil health. Though green manuring in general is believed to improve the soil fertility, but, it needs some time, right temperature and moisture for decomposition. Hence, it may not be possible across all agro-climatic zones. Therefore, brown manuring was found to be a better option (Maitra and Zaman, 2017).

Other uses of green manure crops

- Catch crops
- Shade crops (to provide shade in young orchards besides adding N and improving fertility)
- Cover crops (Covering the bare soil or fallow lands with vegetative cover in hill slopes during rainy season and avoid soil, water and wind erosion besides suppressing the weeds)
- Forage crop: provide fodder

Constraints in green manures and green leaf manures

- Needs land, labour, water, time, money, energy and resources
- Needs optimum moisture and temperature for proper decomposition and release of nutrients
- Immobilization problems if GM or GLMs are not properly decomposed with in a stipulated time
- Pest and disease menace. For eg. leaf webber in *Dhaincha*, yellow vein mosaic virus in pulses *etc*. The green manure crops like sesbania, sunhemp and rapeseed crops act as breeding sites for multiplication of *Spodoptera litura* (Tuan *et al.*, 2014).
- They harbour snails and slugs which may affect the growth of vegetable crops (Becker, 2001)
- They harbour wild boars which will damage near by food crops like corn, jowar, groundnut etc.,
- Amount of biomass available for GLMs may be limited in certain areas especially in semi-arid zones. Transportation is another constraint in GLMs if the trees are located far away from village fields (Weerakoon and Seneviratne, 1984).

Scope and opportunities for green manuring

The green manuring can be adopted in

- Irrigated wet land i.e. rice ecosystem
- Irrigated dry lands
- Rainfed dry lands (hardy species)
- Before *kharif* rice if 40-60 days period is available
- If 40-60 days time gap is available between two rice growing periods
- In rice fallows, if the water is meagre for subsequent crops

Opportunities for green manure seed production

Seed production of green manure crops is very important to meet the ever growing demand for seed. Seed yield of 4-5 q ha^{-1} under rainfed conditions and 12.5-15.0 q ha^{-1} under limited irrigation conditions (1-3 irrigations depending on soil, climate and crop) is possible. It can be produced in the following areas.

- In rice fallows: seed production of green manures after *kharif* rice if water is scarce for second rice
- In fallow/vacant lands and waste lands
- During initial 3-4 years of fruit orchards where lot of unutilized space between rows and saplings is available
- Alley cropping in forest tress species
- Relay cropping in rice fields
- Under rainfed conditions in slopy areas where growing regular field crops may not be possible
- Under rainfed conditions in steep slopy catchment areas of watersheds. It helps in covering the land surface in the catchment area at a faster rate. Further, it covers the land surface for 4-5 months during monsoon season, suppresses unwanted weed growth and arrest the run-off and erosion of soil into water harvesting structures (eg. farm ponds).
- Green leaf manuring can be encouraged by promoting planting of suitable tree species in the villages under Haritha Haram programme (*planting of saplings*) under M-NREGS (Mahatma Gandhi National Rural Employment Guarantee Scheme)

CONCLUSIONS AND FUTURE SCOPE

Green manure crops can fix atmospheric N and supply part of it to the crops grown in sequence. They play a greater role in promoting organic farming. They can reclaim alkaline soils, save N to be applied to crops, improve the availability of many essential nutrients, enhances nitrogen use efficiency, soil health and quality and crop productivity. Their cultivation has to be encouraged in rice fallows, vacant degraded lands and watershed areas. In view of numerous benefits, farmers must be convinced and encouraged to grow green manure crops for *insitu* incorporation. The on-going rural employment guarantee schemes can be taken as an advantage to promote planting of green leaf manure trees and shrubs, which in turn can be utilized for green leaf manuring by farmers. However, farmers need to be provided suitable machinery like cage wheels, rotavators, disc harrows etc., through custom hiring centres, for incorporation of green manures and upscaling the technology. Further research need to be conducted to find out contribution of green manuring in N fertilizer savings in rainfed and irrigated dry crops and also identify low cost non-chemical methods for controlling the pest and disease menace in green manure crops. Furthermore, possibility for apiculture nearby green manure fields should be explored.

Conflict of Interest. Nil.

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