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Green Manurs and Grean leaf manures for soil fertility improvement: A review

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Abstract

No crop will grow well without adequate nutrition and it has to be remembered that maximum performance will depend on a good nutrient balance, adequate moisture levels and an appropriate pH. As a rule short term green manures should not need additional fertility inputs as long as nutrient balances are addressed. Green manures as fertility building crops, they have been used in traditional agriculture for thousands of years but conventional farming systems largely rejected them as the use of fertilizers and pesticides became more common. Although they have many roles they are still often under utilized by today's organic farmers. However, recent emphasis on reducing the environmental impact of all farming systems has led to a growing interest from the conventional sector. A wide range of plant species can be used as green manures. Different ones bring different benefits and the final choice is influenced by many considerations which will be discussed in this review. If the most is to be made from green manure crops it is important that they are carefully integrated into the crop rotation and proper attention paid to their husbandry.

Keywords: green manure, green leaf manure, soil fertility, incorporation, sustainable agriculture

Introduction

Quality food grain production under intensive agricultural management practices is possible by doubling the use of energy and nutrient consumption. Present developed hybrids and high-yielding varieties with different duration groups are not producing the actual yield potentiality under all ecologies. This is mainly due to use of synthetic fertilizers and pesticides which is inevitable. Moreover, soils of Telangana state are comes under the category of Light soils with marginal fertility and present intensive agriculture has resulted in gradual degradation of soil organic matter (SOM) because of the breakdown of stable soil aggregates and decomposition of organic matter (OM). Consequently, soil health is deteriorated in terms of reduction in water holding capacity (WHC) of soils, surface and ground- water pollution, and multiple nutrient deficiencies. Soluble nutrient is provided by synthetic fertilizers for crop production that are easily vulnerable to loss, if soils and irrigation water are not properly managed. Moreover, higher application of synthetic fertilizers has led to an imbalance of the nutrient cycle, particularly N, illustrated by the growing accumulation of several reduced (NH_3) and oxidized (NOx, N_2O, NO −) forms causing water pollution (NO−), air pollution (NOx) and climate change (NO). There are severe concerns about sustainable soil productivity, and today most of the Telangana soils have moved into a post-green revolution phase and are facing the problem of stagnation or declining crop productivity. Hence, both farmers and researchers have opted for conservation agriculture practices, resources conservation, and use of green manuring into the farming system to enhance further food grain production while maintaining soil health.

It has been widely reported that leguminous green manure crops play an important role in soil health management and recently received higher attention for improving soil fertility and agricultural sustainability. Green manuring is the practice of incorporation of un-decomposed fresh/dry plant material into soils, both either in place or brought from a distance. In addition to this, green manure legume crops also fix atmospheric N biologically. Biological nitrogen fixation (BNF) is a microbiological process in which atmospheric N_2 is converted into a plant-usable form, which offers an economically attractive and ecologically sound option of reducing external inputs and improving internal resources.

Legume green manuring (LGM) can enhance agriculture sustainability by improving nutrient retention, enhancing soil fertility, by decreasing soil erosion, and reducing global warming. LGM also has a major role to improve the SOC pool, thereby improving soil physicochemical and biological properties. The incorporation of legume green manure crops into soil releases organic substances like organic acid, amino acids, sugars, vitamins, and mucilage during crop growth as well as after decomposition. These substances are capable to bind soil particles together and form better soil aggregation, resulting in increased hydraulic conductivity, water holding capacity (WHC), water infiltration, and total pore space of the soil. Further, the green manure incorporation provides carbon (C) and energy to soil biota required for OM decomposition and nutrient recycling. In the process of LGM, soil pH is changed by addition of OM. The addition of organic amendments into soils, particularly green manure, has potential to control weeds and soil-borne diseases and to disrupt the life cycle of agriculture pest. Green manure is important to small-scale farmers, for whom it is difficult to buy expensive mineral fertilizers. Therefore, legume green manure crops have great potential for sustainable food grain production. An ordinary crop takes about 25 lb (11.34 kg) of nitrogen (N) from an acre. It is, therefore, necessary to replenish the soil with the elements, which are removed by the crops year after year. Depending upon the species and locations, green manure crops supply 40 to 120 kg N ha^{-1} (Shivaram *et al.,* 1991) [22]. This amount would equal an application of three to ten tonnes of FYM on the basis of organic matter and its N contribution. Green manuring being a low cost practice, is an alternate way to improve soil fertility status. It has received a new impetus in recent years with an urgent need for increased food production in the country. Keeping above facts in mind, the objective of this paper is to provide information on the LGM for sustainable soil management and crop production.

Green manure

Green un-decomposed material used as manure is called green manure. It is obtained in two ways: by growing green manure crops or by collecting green leaf (along with twigs) from plants grown in wastelands, field bunds and forest. Green manuring is growing in the field plants usually belonging to leguminous family and incorporating into the soil after sufficient growth. The plants that are grown for green manure known as green manure crops. The most important green manure crops are sunhemp, dhaincha, *pillipesara,* clusterbeans.....*etc.*

Dhaincha

Two species namely *Sesbania aculeata* and *Sesbania rostrata* are important as green manure crops**.**

Sesbania aculeata is a root nodulating potential green manure for nutrient supply and gaining momentum in the context of sustainable agriculture. Commonly cultivated for green manure, fodder, non perennial temporary shade in crop field and as wind breaks. It is root nodulating legume with leaf composition 3.50% N, 0.60% P_2O_5, 1.20% K_2O. It is a quick growing succulent green manure crop, which can be incorporated at about 8 to 10 weeks after sowing. This crop adapts to varying conditions of soil and climate. It can be grown even under adverse conditions of drought, water logging, salinity etc. Recommended seed rate as green manure incorporation is 50 kg/ha. The green matter yield is 10-20 t/ha. Quantity of nitrogen fixed is 75 to 80 kg/ha (A.R. Sharma & A. Ghosh, 2000) [21].

Sesbania rostrata is a green manure crop, which has nodules both on the stem and root. It thrives well under waterlogged condition but sensitive to Alkaline condition. The normal seed rate as green manure is 30 to 40 kg/ha. To get early, uniform germination and vigorous seedlings, seeds have to be scarified with concentrated sulphuric acid for 15 minutes and then washed thoroughly with fresh water and sown immediately. A green matter yield of 15 to 20 t/ha which is equivalent to 150-180 kg N/ha and obtained within a period of 8 to 10 weeks. Suitable to preceding Paddy and other rainfed crops (Ward Capoen *et al.,* 2010) [5]

Sunhemp

Crotalaria juncea is a vigorous growing green manure crop, which can be incorporated at 10 weeks after sowing. It does not withstand heavy irrigation & water logging. The seed rate for green manure incorporation is 45-50 kg/ha. The green matter yield is 15-20 t/ha. Quantity of nitrogen fixed by the crop is 75-80 kg/ha. Sunhemp is the most outstanding green manure crop and is well suited in almost all parts of the country and fits in well with the sugarcane, cotton, orchards, agro-forestry systems, garden crops, paddy and other rainfed crops in Southern India and with irrigated wheat in the Northern India. It's leaf composition is 2.30% N, 0.50% P_2O_5, 1.80% K_2O (Javaid *et al*., 2015) [7].

Pillipesara

Phaseolus trilobus is a dual purpose crop yielding good fodder and green manure. Herbaceous creeper grows into a short dense cover crop if sown thick (Navpreet Kaur *et al*., 2012) [9]. Does not produce a bulky yield, it is capable of being cut twice or thrice before being ploughed into the field. It is grown in all seasons and suitable to rice fallow clay soils. As green mater will be incorporated within 60 DAS and for seed harvested at 150 DAS. 10-15 kg seed/ha is required for green manure purpose. Green biomass production is 6-7 t/ha and seed yield recorded is 400 - 500 kg/ha.

Wild indigo or kolingi

Tephrosia purpurea is a slow growing green manure crop. It is not grazed by cattle and is suitable for light **s**oils. It resists drought but does not withstand water stagnation. The seed have a waxy, impermeable hard seed coat and do not quickly germinate. To hasten germination, the seeds are to be abraded with sand or steeped in hot water at 55°C for two to three minutes. The seed rate required as green manure is 20-25 kg/ha and the green matter yield varies from 8 to 10 t/ha. When kolingi is sown in an area for two or three seasons continuously, scattered seeds will give rise to volunteer plants and there is no need for further sowing (Sagar *et al*., 2018) [15].

Pigeon pea

Cajanus cajan cultivation would be able to provide 40-60 kg N/ha to the subsequently grown crop. The leaves and immature stems can be used as a green manure. Fallen leaves also return organic matter, which helps in preventing erosion due to heavy rains, and reduces soil temperature. The extensive root system of *Cajanus cajan* improves soil structure by breaking plow pans, and enhancing water holding capacity of the soil. Its deep taproot is able to extract nutrients (e.g. P) from the lower layers of the soil and deposit them in upper layers where they can benefit other crops. 75 days after incorporation and decomposition reported C/N ratio as 14.4, N content 29.99 g/kg litter bag, P content 3.0 g/kg, K content 19.91g/kg, Ca content 7.21 g/kg, Mg content 2.50 g/kg (Smritikanna *et al*., 2018).

Green gram (*Vigna radiata*)

It produces high biomass (2.9 to 4.4 kg/ha). A short vegetation duration (60 to 75 days), has a pH of 5.2, OC of 27%, high OM of 79%, N 3.6%, P 2440 ppm., C:N 6.75, K and Mg of 29.6 and 11%, respectively. Seed rate required is 30 kg/ha. Nitrogen fixation reported as 38-50 kg/ha (Naci Algan and Esen Çelen, 2011) [12].

Soybean (*Glysine max*)

The vegetative portions may be plowed under as a green manure. The majority use of soybean in sugarcane production as a green manure crop for almost a century. Soybeans accumulate about 280 to 360 kg N/ ha. Bean plants all the beans, pods, leaves, and stems will contain about 3% nitrogen, or about 60 pounds of nitrogen per dry ton of bean biomass. Most fields will have between one and two tons of dry biomass so more than 60 pounds of nitrogen per acre can be made available to next crop if incorporated into the soil as a green manure. This also will return other minerals and organic matter to the soil.

Cowpea (*Vigna unguiculata*)

Cowpea, *Vigna unguiculata* (L.) Walp., most productive, heat adopted and is well adapted to acid upland soil and can be grown for green manure. Cowpea green manure accumulated on average 68 kg N/ha, and above ground residue after harvest of dry pods contained on average 46 kg N/ha as pre rice cultivation. Profuse nodulation and ensuing symbiotic nitrogen fixation, when grown in low fertility soils within droughty climatic regions, contribute greatly to cowpea value for soil improvement. Its long taproot and wide, vegetative spread make it an excellent plant for erosion prevention and weed suppression. Allelopathic compounds in the plant may help to suppress weeds (Clark, 2007). It has also been used successfully as groundcover in orchards and intercropped with cash crops such as cotton. Around 40 kg seed required per hectare as green manure and contains 1.4 - 1.5% N. Produces 9-10 tonnes of Green matter (Muñoz *et al*., 2016) [11].

The contribution of green manure, as a nitrogen source, was equivalent to 30 kg N ha^{-1} when no fertilizer nitrogen was applied in menthol mint. The residual effect of cowpea GM was studied in a succeeding crop of fast growing essential oil yielding palmarosa (*Cymbopopogon martinii* (Roxb.) Wats. var motia Burk.) over two harvests (July and December). Averaged across N levels green manure resulted in an increase of 18.5% in the fresh biomass and 17.7% in essential oil yield of palmarosa over no green manuring.

Groundnut

Groundnut (*Arachis hypogea*) is also cultivated as a cover crop, forage, green manure, intercrop, and for hay. Its cultivation improves soil fertility through atmospheric nitrogen fixation (Lal, 2008). In a comparative study of Groundnut with sunhemp, 18 g N per centiare (one square meter) was calculated as the amount of nitrogen fixed at the late maturity stage. The percentage of nitrogen fixed to the total nitrogen was 60-70% in both legumes. On the yield and nitrogen uptake of the succeeding wheat, the Groundnut plot was superior to the sunhemp plot. The percentage contribution of nitrogen accumulated by each legume to total nitrogen of the succeeding wheat was 11.2% on the groundnut plot and 9.4% on the sunhemp plot. In peanut, the C-N ratio was approximately 20 at time of incorporation. In sunhemp, it was 40, and the decomposition rate was found to be slower than that of groundnut. The results indicated that peanut crop contributed more nitrogen to the succeeding wheat compared with sunn hemp (Yano *et al*., 1994) [24].

Cluster bean

Guar (*Cyamopsis tetragonoloba* [L.] Taub.), also known as cluster bean, has traditionally been used as a fodder and vegetable crop. Because of its ability to fix nitrogen and because it has a smaller seed than other legumes, it is also used as green manure. Cluster bean is a legume. This means that it captures nitrogen that is in the air to help it to grow. Therefore when it is dug in, as a green manure, it increases the amount of nitrogen in the soil available for the next crop.

It was found that mineralization of urea amended soil was at par with enriched gaur. Cumulative mineralization from green manures followed the order: gaur followed by dhanicha followed by cowpea. Rate of mineralization peaked after 35 DAT. There was significant relationship between net ammonification and mineralization. Cumulative mineralization from green manures was positively correlated with total N, where as lignin content and C/N ratio were negatively correlated. Lignin was the best predictor of mineralization which can explain 80% of total variations. Experiment was conducted in submerged soil system (Bhatt *et al*., 2016) [4]

Black henna

Indigo (*lndigofera tinctoria* L.), locally known as "tayum”, is a shrubby legume that was initially introduced as a source of dye but was adopted by farmers as green manure (GM). It grows slowly during the first three months from planting. Thereafter, the plant grows rapidly. In 210 days, indigo intercropped with dry season (DS) crops could accumulate biomass amounting to 2.1 – 2.6 t / ha.. This could contribute about 38 – 71 kg organic nitrogen (N) per hectare. The slow growth rate of indigo is an adaptive advantage, as it would allow indigo to be established through intercropping scheme (Sagar *et al*., 2018) [15].

Barseem

Trifolium alexandrinum, annual clovers had greater biomass yields than perennial clovers, and berseem clover had the highest yield. Mean biomass N content reported was greater for perennial clovers (2.9 g N/ kg) than annual clovers (1.9 g N/ kg). Clover biomass yielded an average of 77 kg N/ ha, with N derived from the atmosphere averaging 88% by N difference method and 75% by 15N natural abundance method. The green manures had few effects on soil nitrate and subsequent barley yields. All clover green manures except balansa increased barley yields, and grain yields were greater following perennial clovers than annual clovers in one year. Annual clovers will provide forage biomass and add N in areas where rainfall is adequate, and they may be preferable under zero tillage. However there is no advantage of annual clovers, relative to perennial clovers, in terms of N supply (Ross *et al*., 2008).

Broadbean

Vicia faba in terms of biomass production capacity, the most suitable results were observed in the sole fababean (96.4 t/ ha) and the fababean + triticale mixture (81.8 t/ ha) and dry biomass yield ranged from 12.9 to 28.9 t ha^{-1}. The sole fababean and its mixtures with grasses suggested with priority due to the high amounts of biomass production, while at the same time providing the soil with nitrogen, and that it would make for a suitable application to grow legumes in sole stands or as mixtures and incorporate them into the soil as green manure. Additionally, while it may be seem to be a positive outcome for annual ryegrass and triticale to deposit generous amounts of root residue, due to having fibrous root structures, it is recommended that their mixture with fababean should be preferred (Karkanis *et al*., 2018).

White lupin

White lupin (*Lupinus albus)* grew well in alkaline conditions. The entire plant is exploitable as green manure during soil phyto-remediation. Winter cultivation of white lupin in sequence with a metal-accumulator summer crop can improve the recovery of soil quality during the phyto-extraction period. It improves the safety of the area, limiting additional ecological and human health problems, and enhances soil health by avoiding the use of chemical amendments and by increasing the levels of viable micro-organisms. It was reported, when well nodulated, the rhizobia associated with lupin (*Rhizobium lupini*) can fix between 150 and 350 kg N/ha/year, up to 79% of the crop's N requirement (Pietro Fumagalli *et al*., 2014).

Common vetch

Vicia sativa L. (Common vetch) is a multipurpose, cool season, annual legume, well adapted in Mediterranean region, East Europe and Western Asia. Common vetch is desirable as green manure mainly for the ability to form vigorous root system that develops nodules at early stages and fixes atmospheric N into the soil. In plant density of 180 kg/ha higher biomass was recorded for genotype Alexandros (7.5 t/ ha), Mix1 (7.3 t/ ha) and Mix2 (7.2 t/ha), 140 days after sowing, just before the incorporation of plants into the soil.

Lupins also possess specialized acid-secreting cluster roots which make them particularly efficient at obtaining phosphorus from the soil. Decomposition processes, which are stimulated when green manure residues are incorporated into the soil, can further increase P availability by releasing CO2, which forms H_2CO in the soil solution, resulting in the$_3$ dissolution of primary P-containing minerals (Müller *et al*., 2015).

Fenugreek

Trigonella foenumgraecum an attractive and easily managed green manure crop that can be sown in autumn in warmer areas, otherwise sow in spring. The thick mat of foliage will suppress weed seeds and provide a nitrogen rich resource to the soil. Fenugreek Green Manure is a quick growing annual that can be ready to dig in 10 weeks from sowing. It can be sown from March to August and performs best on well-drained but slightly heavy soils. It will tolerate lighter ones if they are fairly moist.

Fenugreek is an attractive bushy plant that is suitable for summer sowing and produces small white flowers with lots of bushy foliage but it is best to incorporate before flowering. It is part of the Legume family and should be treated as such for crop rotation purposes. However it can only fix nitrogen if the appropriate bacteria are in the soil (Ahmad *et al*., 2016) [2].

Trefoil

Yellow Trefoil (*Lotus spp.***)** is great for inter-planting taller crops which have open canopies like beans, tomatoes, potatoes, sweetcorn & especially long-standing brassicas which overwinter. It is however mainly grown as a summer green manure to help against weed suppression and retain soil moisture.

Trefoil is an excellent Nitrogen fixer making it perfect for use as Green manure. It does not like acid soil but will tolerate some shade and is ideally suited for under sowing, for example between rows of sweetcorn, asparagus, beans or soft fruit. This species has a symbiotic relationship with certain soil bacteria, these bacteria form nodules on the roots and fix atmospheric nitrogen. This nitrogen can be used for the benefit of current or future crops by digging in late winter / early spring (Sagar *et al*., 2018) [15].

Lucerne or alfalfa

Alfalfa (*Medicago satvia*)**,** is an important perennial legume that is used as forage crop worldwide and it is also a very good green manure resource, with a high P concentration (0.30–0.42% of dry weight) that far exceeds the amount of P in most plants, which ranges from 0.05% to 0.30%. A hardy perennial normally grown as a short-term (2-3 month) green manure. Adds bulk plus some nitrogen fixation to the soil. Seed rate of 10 kg/acre (2.5 grams per sq.m.) is recommended. Acidic or waterlogged soils soils are not suitable (Nxumalo *et al*., 2010) [13].

Green Leaf manures

Application of green leaves and twigs of trees, shrubs and herbs collected from elsewhere is known as green leaf manuring. Forest tree leaves are the main sources for green leaf manure. Plants growing in wastelands, field bunds etc., are another source of green leaf manure. The important plant species useful for green leaf manure are neem, mahua, wild indigo, Glyricidia, Karanji *(Pongamia glabra)* Calotropis, Avise *(Sesbania grandiflora),* Subabul and other shrubs.

Gliricidia

Gliricidia (*Gliricidia maculata*), is a shrub, spread by massive campaign in India during 1950s which takes up a tree habit under favourable conditions of soil and climate. For green leaf purposes, the shrub should be kept low by pruning or lopping at a height of 2-3 m. The shrub can be pruned two or three times a year and it withstands repeated lopping. Within two years after planting, the plants are ready for lopping. Each plant gives 5 to 10 kg of green leaves annually. Leaves contain 2.76% N, 0.28% P_2O_5, 4.60% K_2O (Abdul *et al*., 2001) [1].

Quick growing tree are often used for shade and green leaf manure in tea, coffee and cocoa plantations. It can be planted on alternate field bunds of wetland, 1 to 2 m apart, or as a thick hedge by close planting in three to four rows at 0.5 m spacing or along field border as tall shrubs giving support to the fence line or along farm roads on both sides for the production of green leaf. Glyricidia do not affect the growth of cultivated crops with their shade effect. Glyricida can be propagated by planting stem cuttings or seedlings

Neem

The farmers are applying neem (*Azadirachta indica*) leaves to rice fields as green manure traditionally. Neem cake blending of urea is recommended for inhibition of nitrification and increasing nitrogen use efficiency. Application of fresh neem leaf at 5 t/ha or dry neem leaf 1.25 t/ha with urea resulted in higher N recovery per cent and N response ratio and gave increased grain yield in paddy compared to the yield obtained due to the application of urea alone. Besides increasing the grain yield, neem leaf application could save about 50 per cent N application and give greater net returns to the farmer.

Profusely branching, large ever green tree and gives plenty of foliage. It comes up in all types of soil. The trees are 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 to 6 m. One or two lopping in a year are taken in favourable seasons, each lopping weighing about 150 to 200 kg of green matter. Leaves contain 2.83% N, 0.28% P_2O_5, 0.35% K_2O (Santhi and Palaniappan, 2008) [17].

Karanj

Karanj (*Pongamia glabra) i*s one of the nitrogen fixing tree. Incorporation improves soil fertility status in many crops. It is Leguminous, moderate sized ever green tree. It grows in coastal forests, on river banks and on tank bunds mostly along streams, wastelands and road sides. Trees are established by means of planting two to three months old seedlings, 4 to 5 m apart. Lopping may be taken once or twice a year. A tree yields approximately 100 to 150 kg of green material per lopping. Leaves contain 3.31% N, 0.44% P_2O_5, 2.39% K_2O (Usharani *et al*., 2019) [23].

Morning Glory

Ipomoea cornea, quick growing, profusely branching and highly drought resistant weed. It gives abundant green leafy material in short time. It is multiplied by means of mature stem cuttings. Two to three lopping can be taken in a year. Each plant will give about 5 to 7 kg of green matter per lopping (Satish and Nikhil., 2016) [19].

Subabul

Subabul (*Leucaena leucocephala*), this species, a native of Central America, occurs as a branched shrub. It is a promising forage tree crop, the leaves of which contain about 3-4% of *N. Leucaena* fixes about 500-600 kg N/ha/year. Sharma and Behra (2009) [20] reported that combined use of green leaf manuring with *Leucaena* pruning's and urea fertilizer on equal N basis resulted in higher productivity, profitability and more efficient utilization of N, leading to fertility build-up and thus sustainability of maize–wheat cropping system in the long-run.

Cassia

Cassia auriculata a shrub with large bright yellow flowers. Propagated by seeds. During flowering tree is topped (stem and branches cut) and loppings used for green leaf manuring. The plant attains a height of 7mt. In India, the flowering season are mainly two, first is in early monsoon and second is late monsoon. It is valuable as a green manure crop. It prefers a light porous soil. It is immune from browsing by cattle and goats, and plantations are easy and cheap to raise. The cheapest method of cultivation is by sowing in furrows 2 -5 in apart and 4 - 6 in deep. It is native of India. Seed need to be collected in May to June (Sagar *et al*., 2018) [15].

Gulmohar

Gulmohar (*Peltophorum ferrugenum*), is of potential use for reforestation, in agro-forestry farming systems and as a source of green manure. It is a deciduous tree growing to 15–25 m (rarely up to 50 m) tall, with a trunk diameter of up to 1 m belonging to Family Leguminosae. Trees begin to flower after about four years. Used as decorating flower in Telangana State's Batukamma festival.

In India, the general flowering period is March to May, although sporadic flowering may occur throughout the year (particularly in young trees), and a second flush of flowers may occur in September-November. As a fast-growing species, young trees raised from seed will, under good conditions, flower from age 4 years. Leaves contain 2.63% N, 0.37% P_2O_5, 0.50% K_2O. (Amrit Lal Meena *et al*., 2020)

Kassod tree

Cassia siamea, also still commonly referred to by its old name, *Cassia siamea*, *S. siamea* foliage is used as a green manure for fields, where it can make a significant contribution by slow release of nitrogen to the crop and reduce weed control problems, as the leaves break down slowly. *S. siamea* is a medium-size tree rarely exceeding 20 m in height, more usually 10 to 12 m, but which can attain 30 m under exception circumstances. It has a dense, round, evergreen crown and a short bole with smooth, grey bark, slightly fissured longitudinally. In India, the trees are never leafless, though a new flush of leaves is produced in February-March. It is now well accepted that although a member of the Fabaceae (legume family), *S. siamea* does not fix nitrogen through *Rhizobium* symbiosis in nodules (Amrit Lal Meena *et al*., 2020).

Tephorsia candida

Tephrosia candida is a drought-tolerant, nitrogen-fixing shrub. It is commonly used in agro-forestry systems, especially for soil improvement and erosion control. It is also used as a green manure and in extended fallows, contour hedgerows. *Tephrosia candida* varies in habit from an erect herb to a shrub or small tree with straggling branches from the base; it usually grows up to 3.5 metres tall, occasionally reaching 5 metres.

With its ability to fix large amounts of atmospheric nitrogen and produce a good bulk of biomass, white *tephrosia* is widely used in agro-forestry as a green manure crop, to restore degraded land etc. Not only does it provide nitrogen, the plant also raises soil phosphorus and potassium levels in proportion to increased levels of organic matter. Soil structure improves, water-holding capacity and permeability increase, and soil losses caused by water erosion decrease. It can yield well on acid soils; for example, in Vietnam, green-matter content of the soil increased from 1.7 to 4%. Nutrient (nitrogen, phosphorus, calcium, magnesium and potassium) yields in leaves of *T. candida* fallow for 2 yr were on average 200–300% higher than in leaves of other fallows. Nutrient uptake (N, P, Ca, Mg and K) was highest in leaves of *T. candida*, smother weeds in the vicinity. (Ikpe *et al*., 2003) [6].

Dodonea viscos

A fast-growing small tree or shrub that grows 1 to 3 m in height but is capable of reaching 8 m. *D. viscosa* is very effective in sand dune fixation and controlling coastal erosion since its roots are excellent soil binders. It is also used to reclaim marshes. It is a fast growing shrub that requires no management once it is established. It regenerates rapidly after burning. Tree is also widely used to control soil erosion because of its deep root system. It is a good species for agro-forestry. Grows to a height of 10 - 15 feet, width of 10 - 15 feet, growth rate of 24 to 36 inches per year and evergreen (Sanjeev Kumar, 2020) [16].

Delonix elata

Delonix elata is a deciduous tree with a rounded spreading crown and drooping branches, usually growing 5 - 15 metres tall, the bole is usually crooked and of poor form. *Delonix elata* has a widespread distribution and is also cultivated for shade, green manure, among other things. The plant has potential use in soil conservation projects. It has been successfully used in protecting channel and river banks. Fast-growing and fixing atmospheric nitrogen, it is a good tree for reforestation of difficult sites and, with its low crown, is effective as a shelter belt. The leaves are used as a green manure. Rich in Magnesium, they yield 50 - 200 kg of mulch per year (Sanjeev Kumar, 2020) [16].

Sub- tropical grasses and weeds (Sagar *et al*., 2018) [15]

1. *Panicum maximum,*	12. *Cleome viscosa*
2. *Pennisetum purpureum,*	13. *Dactyloctenium aegyptium*
3. *Tripsacumlaxum,*	14. *Digitaria sanguinallis*
4. *Aduthoda vesica,*	15. *Echinochloa crusgalli*
5. *Eicchornia crassipes,*	16. *Portulaca quadrifida*
6. *Trianthema portulacastrum,*	17. *Solanum xanthocarpum*
7. *Ipomoea carnea,*	18. *Trianthem apartulacastrum*
8. *Calotropis gigantea*	19. *Eupatorium spp.*
9. *Amaranthus viridis*	20. *Parthenium hysterophorus*
10. *Cassia occidentalis*	21. *Eichhornia crassipes*
11. *Chenopodium album*	

Non legume Forage crops (Sagar *et al*., 2018) [15]

1. Rye (*Secale cereale*),	8. White alacrity (*Sinapis alba*),
2. Oats (*Avena sativa*),	9. Bristles turnips (*Brassica rapa*),
3. Barley (*Hordeum vulgare*),	10. Beat abduction (*Brassica napus*),
4. Abiding ryegrass (*Lolium perenne*),	11. Fodder raddish (*Raphanus sativus*),
5. Italian ryegrass (*Lolium multiflorum*),	12. Phacelia (*Phacelia tanacetifolia*),
6. Westerwolds ryegrass (*Lolium multiflorum*),	13. Buckwheat (*Fagopyrum esculentum*),
7. Cocksfoot or orchard grass (Dactylisglomerata),	14. Chicory (*Chichorum intybus*)

Table 1: Nutrient content of green manure crops on Air dry basis (Lokesh *et al*., 2015)

S. no.	Plant	Botanical name	Nutrient content (%) on air dry basis		
			N	P	K
Green manure					
1	Sunnhemp	*Crotolaria juncea*	2.3	0.5	1.8
2	Dhaincha	*Sesbania aculata*	3.5	0.6	1.2
3	Sesbania	*Sesbania speciosa*	2.71	0.53	2.21
4	Cowpea	*Vigna sinensis*	1.7	0.28	1.25
5	Mungbean	*Vigna radiate*	2.21	0.26	1.26
Green leaf manure					
6	Gliricidia	*Gliricidia sepium*	2.76	0.28	4.6
7	Pongamia	*Pongamia pinnata*	3.31	0.44	2.39
8	Neem	*Azadiracta indica*	2.83	0.28	0.35
9	Gulmohar	*Delonix regia*	2.76	0.46	0.5
10	Peltophorum	*Peltophorum ferrugenum*	2.63	0.37	0.5
11	Cassia	*Cassia fistula*	1.6	0.24	0.2
12	Calotropis	*Calotropis gigantean*	2.06	0.54	0.31

Table 2: Nutrient accumulation of Major nutrients (kg) & Total micro nutrients (g) (Lokesh *et al*., 2015)

S. no.	Crop	Dry matter in 45-60 DAS (q/ha)	Nutrient accumulation						
			Major nutrients (kg)			Total micro nutrients (g)			
			N	P_2O_5	K_2O	Zn	Fe	Cu	Mn
1	*Sesbania rostrata*	50	131	18.5	62.5	200	9840	180	1050
2	*Sesbania speciosa*	30	119.4	7.2	39	150	1440	132	330
3	*Gliricidia maculata*	35	125.6	125.6	46.8	108	1980	68	540
4	*Eichhornia crassipes*	70	198.1	63	125.3	350	3290	133	2940
5	*Crotolaria juncea*	52.5	150.2	47.3	93.9	262	2467	100	2205
6	*Trianthema spp.*	25	58.5	7.5	28.7	75	4980	47	500
7	*P. hysterophorus*	40	106.4	35.2	51.6	280	1880	76	640

Table 3: Representing the nutrient content in weeds on dry weight basis (Lokesh *et al*., 2015)

S. No.	Weeds	Nutrient content (%)		
		N	P	K
1	*Amaranthus viridis*	3.16	0.06	4.51
2	*Cassia occidentalis*	3.08	1.56	2.31
3	*Chenopodium album*	2.59	0.37	4.34
4	*Digitaria sanguinallis*	2	3.36	3.48
5	*Echinocloa crussgalli*	2.98	0.4	2.96
6	*Portulaca quadrifida*	2.4	0.09	5.57
7	*Solanum xanthocarpum*	2.56	1.63	2.12

8	*Trianthema partulacastrum*	2.34	0.3	1.15
9	*Parthenium hysterophorus*	2.66	0.88	1.29
10	*Eichhornia crassipes*	2.83	0.9	1.79

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