Green Manure: A complete nutrient source for sustainable soil health in modern agriculture

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ABSTRACT
The recent advancement of agricultural technologies has undoubtedly increased the agricultural production and productivity across the world. However, excess use of synthetic fertilizers and other agro-chemical have led to degradation of soil fertility and stagnation of crop productivity due to lower soil organic matter content and poor microbial diversity. Therefore, maintenance of soil health and sustainability of agriculture production have become the crucial concern for agriculture research. Because of their versatile impacts on soil physico-chemical and biological properties, green manures can play a crucial role in maintaining soil fertility. Use of green manures along with other crop residues and organic manures have now become the necessary for holistic agricultural production system and sustaining soil health in modern agriculture. Keywords: green manures, soil fertility, sustainability, soil health, soil degradation.

Management of soil fertility/health at an adequate level in modern agriculture is one of the most crucial factors to achieve the higher crop production which can be achieved through application of suitable soil and crop management practices. In modern agriculture system, farmers are mainly dependent on use of different synthetic fertilizers and agro-chemicals to achieve the desired level of soil fertility and higher level of crop production. But excess use of these synthetically developed agro-chemicals have degraded soil fertility as well as adversely affecting the environment and animal health (Fageria, 2007). Incorporation of organic nutrient sources including green manures is becoming an important strategy for improvement of soil fertility in modern sustainable crop production. Research across the globe has proved superiority of green manures for restoration of soil fertility/productivity as compared to inorganic fertilizers.

Use of diversified organic nutrient sources i.e. compost, farm yard manure, vermin-compost, liquid organic manures, enriched compost, oil cakes, green manures (GM) etc. are recommended as an alternative source for restoration of degraded/eroded soils and also recommended for improvement of soil productivity and fertility for sustainable crop production (Kumar et al., 2018). At the same time, these organic sources reduce the load of chemical fertilizers. Incorporation of degraded or fresh organic manures green manures) into the soil is directly related to the agricultural potential of soils. Among the various organic nutrient sources, green manures have been considered as complete manure as production and incorporation of green manure supply all the essential plant nutrients in the soil.

Green manuring technology is becoming a promising tool for maintenance of soil fertility and productivity in the longer run under modern sustainable agriculture due to presence of large biomass and high nutrient content as well as release of nutrients during the whole cropping cycle after incorporation in the soil. Turning of under composed green plant material in the soil not only provide organic matter in the soil but also can be used as an alternative for improvement in soil physico-chemical and biological properties (Fageria, 2007). The proper knowledge and attention about the composition, rates and placement of green manure crops can drastically reduce the use of chemical fertilizers. Appropriate practice of green manure crops has been found a suitable technique for weed control and pest management in various studies conducted by many researchers. Furthermore, incorporation of green manure crops in crop rotation with cash crops disrupts the insect pest, weeds and diseases of the cash crops. Inclusion of green manuring in environmentally sustainable, socially acceptable and economically viable dynamic cropping system improve soil fertility through increased nutrient retention and decreased soil erosion.

Historical Perspective of Green Manuring
Green manuring is an age old practice through the world. During 300 B.C. use of faba beans (Viciafaba L.) and lupine (Lupinus sp.) as green manure crops was very common practice in the Roman Empire. Addition of organic matter in the soil through oats (Avena sativa L.), buckwheat (Fagopyrum esculentum G.) and rye (Secale cereale L.) as green manure was very famous in North America during early ages. In India, growing of leguminous crops as an important source of nitrogen for wetland rice is a common practice much before the
introduction of modern agricultural practices (Singh et al., 1992). Sowing and incorporation of legume crops as soil-conserving and soil-improving crops is being practice in Indian Agriculture since ancient period. During early years of agriculture, natural resources were the major source of soil productivity which maintained the sound ecological equilibrium between human-animal-plant and soil.

Development of agricultural science and technology after Second World War has declined the use of organic manures due to development of cheap synthetic fertilizers for maintaining soil fertility and crop productivity. But since last two decades the detrimental effects of different synthetic fertilizers and other agrochemicals have generated the interest of farmers in organic manures, especially green manure, due to their rapid decomposition rate and high nutrient contents.

**Definition of Green manuring**

Green manuring is the process of soil incorporation or ploughing under any green plants either by raising them in the field itself or plants grown elsewhere at the green stage or soon after the flowering. Green manures are leguminous crops or forages which are grown for soil conservation through incorporation of their leafy materials. It can also define as practice of soil enrichment through turning of fresh plant materials either in-situ or brought from distance “is widely acceptable practice for soil organic matter enrichment in modern agriculture”. Green manure crops have properties like short duration, rapid growth and production of large quantity of organic matter and thus release N, P, K and other plant nutrients. Leguminous green manure crops have capability of fixing atmospheric nitrogen through nodule formation in their roots.

**Needs of green manuring**

The soil accompanying constraints i.e. inappropriate soil management, affre of crop residues, non-judicious agronomic practices, asymmetric nutrient management, and depletion in soil organic matter, scant/limited use of organic and bio-fertilizers and excess use of chemical fertilizers have led decline in crop production and stagnation in crop yields in Indian Agriculture in last two decades. These things have created a serious threat for sustainable crop production. Reduced organic matter content in soil leads to poor soil water relationship and thus results in poor nutrient mineralization from organic solution and lower cation exchange capacity. The only solution for sustainable crop production is inclusion of organic manures in the practice especially green manures (Salahin et al., 2013). Green manuring has capacity to fix atmospheric nitrogen and also provides large biomass which stimulates the microbial diversity and ultimately improves the soil fertility. In addition, it releases the nutrient throughout the cropping cycle.

**Crops for green manuring**

Green manuring is the commotion of agronomic processes and incorporation of green legume and non-legume plants into the soil either in-situ or plants grown elsewhere for abundance improvement. Green admixture crops ca be the grain legume crops such as: green gram (Vigna radiata), pigeon pea (Cajanus cajan), cluster bean (Cyamopsis tetragonoloba), soybean (Glycine max), cowpea (Vigna unguiculata) or groundnut (Arachis hypogea); non-grain bean and aroma legumes like dhaincha (Sesbania species, S. aculeata), sunn hemp (Crotalaria juncea), black henna (Indigofera tinctoria), wild indigo (Tephrosia purpurea), broadbean (Vicia faba), Barseem (Trifolium alexandrinum), blue lupin (Lupinus angustifolius), white lupin (Lupinus albus), yellow lupin (Lupinus luteus), fenugreek (Trigonella foenum-graecum), trefoil (Lotus spp.), black medic (Medicago lupulina), lucerne or alfalfa (Medicago satvia), strawberry clover (T. fragiferum), white clover (Trifolium repens), red clover (Trifolium pratense), Persian clover (Trifolium resupinatum), subclover (Trifolium subterraneum), candied clover (Mellilotus spp.), Perennial coarse multipurpose shrubs i.e. Gliricidia spp., Leucaena leucocephala (Subabul), Cassia auriculata, Cassia siamea (Kassod tree), Azadirachta indica (neem), Derris indica, Cassia accidentalis, Cassia tora, Dodonea viscosa, Tephrosia candida, Delonix elata, Hibiscus viscosa, Peltophorum ferrugenum, Delonix regia, Vitex negundo, Cassia nigricans.

Other these plants many sub-tropical grasses and weeds viz. Pennisetum purpureum, Panicum maximum, Aduthoda vesica, Tripsacum laxum, Eichhornia crassipes, Triandhemia portulacastrum, Ipomoea carnea, Calotropis gigantean are also advised to use as green manuring because of their abundance biomass. Many non-leguminous crops and forages i.e. oats (Avena sativa), rye (Secale cereale), abiding ryegrass (Lolium perenne), barley (Hordeum vulgare), Italian ryegrass (Lolium multiflorum), Westerwolds ryegrass (Lolium multiflorum), orchard grass (Dactylis glomerata), bristles turnups (Brassica rapa), beat abduction (Brassica napus),
fodder raddish (*Raphanus sativus*), Phacelia (*Phacelia tansyfolia*), alacrity (*Sinapis alba*), buckwheat (*Fagopyrum esculentum*), white chicory (*Chichorium intybus*) can also be used as green manure crops (Sinha et al., 2009).

**Improvement of soil health and fertility enhancement**

Research studies of modern scientific era across the globe have observed that incorporation of green manure crops in the cropping systems has proved their ability to improve the various soil physico-chemical and biological properties, reduced nutrient losses through leaching and increased water holding capacity of soil. Additions of green manuring in cropping sequence have been found beneficial for increase in soil organic matter and higher nutrient recycling (Ziblim et al., 2013). Inclusion of legume green manure is cropping sequence enhance the soil microbial biomass which results in higher soil ecology, improved microbial diversity, increased soil enzymatic activity which played a crucial role in atomization of organic nutrients through mineralization of nutrients. Green admixture supplies nutrient affluent in organic carbon for microbial biomass which further converts the residual nutrients into accessible form for the plants and increase soil-plant quantum. Leguminous green manure crops can fix the atmospheric nitrogen and can accommodate the organic nutrient in soil whereas; non-legume green manure can access the organic nutrients.

Green manuring technology has been found beneficial because of its nature of non-polluting, eco-friendly, non-hazardous to soil, water and air. Also they do not exhibit any negative effect on food commodities. The high nutrient content and lower C: N ratio increases the value of green manures as better organic fertilizers in sustainable soil health management. Conjoint use of green manure and other crop residue along with crop rotation has been found a useful tool for restoration of soil fertility, better nutrient cycling at farm level, recycling of nutrients from lower soil layers, hamper growth of weeds and reduced the dependency on external source of nutrients. Green manures have been identified as soil fertility building crops. In general, these crops have been found as soil organic matter and nutrient enrichment crops, nutrients and soil conservators, biochemical activity enhancers, improvement in soil porosity, rooting depth and water infiltration and ultimately crop health and yield (Bhattarai et al., 2012). Though, replenish of nutrient in soil and enhancement of organic matter is the major objective of green manure, but they also reduced the nitrate losses and lower nitrogen application through fertilizers in succeeding crops. Green manure plants are sown to restore productivity of exhausted land, to provide shield to soils from erosion, substitution of chemical fertilizers and reduction of nitrate leaching.

**Conclusions**

The anthropologically induced soil degradation due to faulted agronomical practices has created ample loss of soil fertility. Because of their influential impacts on soil physico-chemical and biological activities, green manures can play crucial role in restoration of degraded soil fertility/productivity. Along with improving soil health green manures have ability to fix atmospheric nitrogen and thus reduce the load of nitrogen application from chemical fertilizers. Besides their nutrient supplying capacity and soil biodiversity, green manure plants also help in managing insect-pest and weeds for sustainable crop production. In conclusion, it can be said that to attain the sustainable soil health and crop production, green manuring can be one of the better option in modern agriculture system.

**References**


