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A review on soil health and fertility management in organic agriculture through green manuring

Vinod Kumar and Kirti Pawar

Abstract
The importance of green manuring is very eminent in crop production since the green revolution era. It not only improves and maintain soil structure, tilth & fertility but also ameliorate soil problems, improves crop yield, pest control, weed control & disease control. Green manuring has a great influence on availability of important plant nutrients such as Nitrogen, Phosphorus, Potassium, micronutrients and also increases the water holding capacity of soil. The objective of this article is to review the role of green manuring practice and its impact on crop production and its quality along with maintaining the soil health. India has maximum number of organic growers. It was recorded that 6.7 million hectares area is covered under green manure, which accounts for 4.5 per cent of net sown area (142 million ha) of the country.

Keywords: Crop production, green manuring, fertility, micronutrients, soil structure, tilth

Introduction
Since the Green Revolution of the 1960s, the national agricultural policy is driven by the need to maximize crop yield, using irrigation and intensive use of HYVs, chemical fertilizers, and pesticides. Imbalanced and inadequate use of chemical fertilizers, absence of organic manures, monocropping and intensive irrigation has an adverse effect on soil fertility and productivity in terms of nutritional disorder, micronutrient deficiencies, decline in soil organic carbon, poor soil physical condition, salinity and alkalinity, poor soil biological activity and outbreak of pest and diseases. These have impact on our food security and livelihood supporting system. There are severe signs of health risks due to use of agro-chemicals in general and of synthetic pesticides in particular comparative consumption of fertilizers (NPK) in rainfed and irrigated farming areas (Srivastava *et al*. 2016). It is now well established fact that organically managed soil exhibits greater soil organic carbon & total nitrogen, lower nitrate leaching (Drinkwater *et al*., 1998) & biological soil quality (Loknath *et al.*, 2006, Yakovchenko *et al.*, 1996).
Green manure crops have been used in traditional agriculture (before 1960s) for thousands of years but conventional (chemical) 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 utilised by today’s organic farmers. However, recent emphasis on reducing the environmental impact of all farming systems (stimulated by new legislation) has led to a growing interest from the conventional sector. Green manure is produced a biomass by sown crop parts to mixture with soil on a field so that they serve as a mulch and soil amendment. The green manure plants are used for often cover crops grown primarily for this purpose. Green manure is commonly associated with organic agriculture and can play an important role in sustainable annual cropping systems. Green manures usually perform multiple functions that include soil health improvement and soil protection.
Green manuring helps in, structural improvement of soil and its tilth, fertility improvement of soil, Amelioration of soil problems, improvement of crop yield and quality, pest control and population of soil micro flora (Bacteria, Fungi and Actinomycetes) and enzymatic activity (dehydrogenase and phosphatase) were found. Plant growth promotion will be observed due to increased microbial activities leads to production of enzymes, harmones and metabolites, bio-control of plant insect pests, pathogens, enhancing metabolic activity in plant, production of plant alkaloids and natural metabolites. Systemic resistance being harnessed and has a great potential in organic farming.India has maximum number of organic growers. It was recorded that 6.7 million hectares area is covered under green manure, which accounts for 4.5 per cent of net sown area (142 million ha) of the country.

Ways of Green manuring
Generally the practice of green manuring in India can be classified in three ways i.e.*in-situ*

green manuring, *in-situ* brown manuring and green leaf manuring.

In-situ green manuring

In this system the short duration legume crops are grown and buried in the same site when they attain the age of 60-80 days after sowing. This system of on-site nutrient resource generation is most prevalent in northern and southern parts of India where rice is the major crop in the existing cropping systems. For *in-situ* green manuring crops used are *Crotalaria juncea*, *Sesbania aculeata*, cowpea, cluster bean, mungbean and few weeds which can be used for green manuring alongwith the common legumes to cater the nutritional demand of crops under organic agricultureare Parthenium, Water hyacinth, Trianthema, Ipomoea, Calotropis.

Table 1: Legume crops for *in-situ* green manuring

S. No.	Common Name	Botanical Name	Season
1	Dhaincha	Sesbania Aculeta and Sesbania rostreta	Zaid / Kharif
2	Sunhemp	Crotolaria juncia	Zaid / Kharif
3	Mung	Vigna radiata	Zaid / Kharif
4	Cowpea	Vigna unguiculata	Kharif
5	Guar	Cyamopsis tetragonoloba	Kharif
6	Senji	Melilotus alba	Rabi
7	Berseem	Trifoliumalexandrium	Rabi
8	Khesari	Lathyrus sativus	Rabi

Table 2: *In-situ* green manuring weeds and their mineral composition on dry weight basis

S. No.	Weed	Nutrient content (%)		
		N	P_2O_5	K_2O
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	Cleome viscosa	1.96	1.53	5.81
5	Dactyloctenium aegyptium	2.78	0.24	1.65
6	Digitaria sanguinallis	2.00	0.36	3.48
7	Echinochloa crusgalli	2.98	0.40	2.96
8	Portulaca quadrifida	2.40	0.09	5.57
9	Solanum xanthocarpum	2.56	1.63	2.12
10	Trianthem apartulacastrum	2.34	0.30	1.15
11	Eupatorium spp.	2.93	0.49	1.47
12	Parthenium hysterophorus	2.66	0.88	1.29
13	Eichhornia crassipes	2.83	0.90	1.79

In-situ brown manuring

Brown manuring is a technique of growing sesbania in standing rice crop and kill them with the help of herbicide for manuring. After killing, the colour of the sesbania residue becomes brown that's why it is called brown manuring. This kind of green manuring is more popular in the states like Odissa which receives highand continuous rainfall.

Green leaf manuring

Green leaves and tender plant parts of the plants are collected from shrubs and tress growing on bunds, degraded lands or nearby forest and they are turned down or mixed into the soil. 15-30 days before sowing of the crops depending on the tenderness of the foliage or plant parts. Gliricidia *(Gliricidia maculate)*, Karanj*(Pongamia pinnata)*, Neem, Wild daincha*(Sesbania speciosa),* Subabool (*Leucaena Leucocephala)* Gulmohar, Peltophorum leaves are generally used for this kind of manuring.

Techniques of green manuring

The optimum benefit of green manuring can be obtained through better understanding of suitable sowing time, stage of GM crop for burial and time interval between burial and sowing of next crop.

Sowing time of GM crops

Sowing time of GM crops for *in situ* green manuring varies according to area specific conditions, available resources and farming situations. The green manure crop can be grown as catch crop during summer season particularly in irrigated agro-ecosystem. The rapid growing crops i.e. sunhemp and dhaincha are sown in the month of April-May and buried during June-July before the planting of main kharif crop. In rainfed and intensive farming areas, dhaincha is used to grow as intercrop with paddy in 4:1 row proportion whereas, sun hemp and cowpea are intercropped in alternate rows with widely spaced crops like cotton, maize and sugarcane and buried in the soil when these crops attain the age of 30-45 days after sowing using hoes or mould board plough. In kharif fallow lands the sunhemp, guar, cowpea and dhaincha are usually sown in June-July and buried inthe month of August-September. This practice is most common in Punjab, U.P., Rajasthan, Bihar and Madhya Pradesh states.

Burial stage of Green Manure crops

Burial time of green manure crops plays utmost importance for obtaining their optimum benefits. The chemical composition of most plants changes identically during growing season. During early period of crop growth, the contents of N, protein and water soluble constituents are maximum, while the amount of fibre, celluloses, hemicelluloses, lignin and the C:N ratio are less. At this stage the tissues of immature plants usually decomposes more rapidly as compared to those of matured plants. It was reported by Singh *et al*. (1992) that the green manure crops are to be buried in the soil when they are 2 months old and two weeks delay in the incorporation of crimson clover and hairy vetch reduced their N content and increased the C:N ratio, cellulose, hemicellulose and lignin contents.

Time interval between GM crop burial and sowing of main crop

The knowledge about time interval between GM crop burial and sowing of main crop is more important as it is essential just to facilitate the complete decomposition of the turned in green biomass. The research findings of Ghose *et al*. (1960) derived from their studies conducted at CRRI, Cuttack that the time interval was not so important when succulent green manure crop of eight weeks age was buried because transplanting of paddy immediately after burying of green manure crop was as good as any other treatment. But it was necessary to give the time interval of 4 to 8 weeks before paddy planting when the 12 weeks GM crop buried in the soil.

Method and depth of burial of GM crop

Method and depth of burial is also important for attaining optimum benefits of green manuring. GM crop should be buried at deeper depth in sandy soils and in heavy soils at shallow depth for proper decomposition. Green manures should not be ploughed in as this buries the plants and the nutrients too deep. Immature crop can decompose at any depth, but mature crop should be buried at less depth. If the weather is dry, green manure crop should be buried at more depth compared to moist conditions.

Present scenario of GM crops

According to Agricultural Statistics (2005), the green manuring supplements 7.55, 1.24 and 4.19 lakh tonnes of NPK in the soil. The state wise data given in Table 3, indicates that 1341.8 lakh tones dry matter produced through GM crops.

Table 3: Status and nutrients Contribution by Green Manure Crops in India

State	Area green manured (Lakh ha)	Expected green & dry matter yield (in lakh tonnes)	Nutrients Contribution (in lakh tonnes)			
			N	P	K	Total
A.P.	27.20	544	3.02	0.49	1.67	5.18
U.P.	11.00	220	1.23	0.20	0.69	2.12
Karnataka	7.30	146	0.82	0.14	0.46	1.42
Punjab	4.25	85	0.48	0.08	0.27	0.83
Orissa	3.55	70	0.40	0.07	0.22	0.69
Gujrat	2.10	42	0.24	0.04	0.13	0.41
M.P.	1.94	38.8	0.22	0.03	0.12	0.37
H.P.	1.30	26.0	0.15	0.02	0.08	0.25
Haryana	1.13	22.6	0.13	0.02	0.07	0.22
Others	7.32	146.4	0.82	0.14	0.46	1.42
Total	67.09	1341.8	7.55	1.24	4.19	12.98

Mineral composition on dry weight basis of *Sesbania*: N= 2.25%, P = 0.37 %, K = 1.25%;
(Source: Agricultural Statistics, 2005)

Effects of Green Manuring on soil and crop production

Nitrogen availability and contribution

Maximum amount of nitrogen is available 21 days after GM crop incorporation as 50 per cent nitrogen of the total crop requirement supplemented by GM crop decomposition and rest 50% may be fulfilled externally in two splits i.e. at 10th day after transplanting and at panicle initiation stage in rice. For early decomposition and nitrogen release from green manure C:N ratio of 1/10 is suitable. Higher C:N ratio may have adverse effect on the seedling of rice. Previous studies show that green manuring in rice enhances the yield from 34 to 96% then untreated control. It also saves 20-35 kg nitrogen/acre. It is suitable for short duration coarse varieties of rice than tall statured basmati varieties.

Effect on crop yield

In most of the studies conducted in different parts of the world the crop yields under organic management are somewhat lower than conventional systems. In developing countries, organic farming methods provided similar outputs and income per labour day to that of high input systems using inorganic fertilizers (Andow and Hidaka, 1998). In Samastipur, Thakur *et al*. (1999) evaluated the impact of green manuring on yields of rice-wheat system and reported that green manuring with dhaincha significantly improved the productivity of rice over other sources, whereas residual effect of green manuring on succeeding wheat was marginal. The studies of Patra *et al*. (2000) conducted in Sambalpur district of Orissa, indicated that there was reduction in the yield of rice to the tune of 15-23 per cent due to alone green manuring as compared to 100% recommended dose of NPK through fertilizers which produced the maximum yield (42.97 q/ ha) of rice. Nair and Gupta (1999) also found 25 per cnt more yield of rice over no green manuring which produced only 34.94 q/ha rice at Pantnagar (UT). Similar findings were also reported by Hemalath *et al*. (2000) at Madurai in Tamilnadu.

Effect on soil physical and chemical properties

The physical properties of soils are affected significantly due to addition of organic matter in the form of green manures particularly with *Sesbaia rostrata* and *Crotolaria juncea* subsequently, marked improvement in soil structure, infiltration rate, bulk density and water holding capacity of soil. The results of studies of Badanur *et al*. (1990) indicated that incorporation of subabool, sunnhemp crop residues were equally effective in increasing infiltration rate of soil while the water use efficiency of sorghum was increased significantly with the green leaf manuring of sunhemp, subabool and fertilizer application over crop residues. Aggregate stability and porosity increased identically with the addition of organic inputs particularly green manures and consequently it improved the soil aeration and water holding capacity of the soils under organic management (Droogers *et al*., 1996). The lower rates of run off and soil erosion have also been reported under organic systems (Logsdon *et al.*, 1993; Reganold *et al*., 1987). Application of organic fertilizers not only provides nutrients to the standing crop but also to the succeeding crop (Jannaura *et al.*, 2014).

Under mineral fertilizers, green manure legumes undergo mineralization before N becomes available to rice. The release of N from green manures generally proceeds very rapidly during the first two weeks followed by much slower rate thereafter (Yadvinder Singh *et al*., 1988). In a laboratory incubation study, the peak of NH_4^+N was observed 7 to 15 days after incorporation, and NH_4^+N then decreased quickly due to N loss. Yadvinder Singh (1991) reported that *Sesbania* GM released 31% N in 20 days and 39% in 40 days after flooding. Palm *et al*. (1988) reported that under field conditions of Sri Lanka, leaves of *S. Sesbania* released 88% N in 14 days after incorporation.

Nagarajah *et al*. (1989) observed that N mineralization from *Sesbania* GM in 83 days ranged from 44 to 81% in four soils. The N release from the GM was influenced by soil pH and texture. Substrate quality, environmental factors, soil characteristics, nutrient supply and management factors affect the decomposition and release of N from legume residues. Wide variations in the chemical composition of plant residues exist. The rate of N mineralization from organic N sources dependent on the concentration of n, lignin and polyphenol, and C:N ratio. Low N concentrations and high C:N ratio can lead to initial net immobilization of N from crop residues and a slow subsequent mineralization. The rate of mineralization generally decreases with increasing plant age and faster for legume shoots than for roots (Yadvinder Singh *et al*., 1992).Hundalo *et al*. (1988) reported that GM incorporation significantly reduced the P sorption capacity of waterlogged soils, again favouring high P content of soil. The effect of GM on increasing the availability of P under waterlogged conditions in more pronounced in acid and sodic soils than in normal soils (Yadvinder Singh *et al*., 1992). Green manuring also favours the solubilization and availability of P from rock phosphate. Katyal (1977) reported to the concentration of water soluble Fe^{2+} and Mn^{2+} which caused release of K from exchange complexes. Hargrove (1986) noted increased concentration of available K in soil amended with green manure in the surface layer, which was ascribed to the recycling of K from the sub surface layers. The organic residues with S content > 15% normally release S during their decomposition. Since gm legumes usually contain > 0.15% S, they will release S during decomposition and hence increase the availability of S in soil. Duxbury *et al*. (1989) observed that addition of alfalfa GM immediately reduced the absorption of SO_4^{2-} relative to the un-amended soil. GM caused marked increase in the soil pH over control soil.

Green manures influence micronutrient availability in soil through changes in oxidation reduction capacity and releasing micronutrients during decomposition. The increase in Fe^{2+} and Mn^{2+} concentration due to reduction of oxides of these elements by green manuring varied from very low (>2%) in sodic soils to as high as 30-fold in an acid lateritic soils Yadvinder singh *et al*., 1992). Nayyar and Takkar (1989) found that Fe deficiency in wetland rice grown on coarse textured soil was more effectively correlated by green manuring than by soil applied ferrous sulphate. Green manuring can also help in controlling Fe chlorosis in rice nursery (Meelu *et al*., 1994a).Dubey *et al*. (2015) reported that green manures improve soil structure, letting more air into the soil and improving drainage. Organic matter helps sandy soil hold more water and not drain so quickly as a result of increased aggregate stability and porosity. Also organic matter reduces rate of runoff and soil erosion. Flooding generally causes a decline in the availability of Zn in soils, which is accentuated by green manuring (Yadvinder Singh *et al*., 1992). However, in sodic soils, green manuring increased the availability of Zn (Swarup, 1987), because of its favourable effect on soil pH. Under flooded soil conditions, soluble and exchangeable Fe and Mn increases at the expense of organic or oxide held metals, and this process provides surfaces of high absorptive capacity on which Zn and Cu may be bound. Chen (1983) observed that green manuring with vetch for three years increased the available Zn content of surface soil from 2.9 mg kg^{-2} in control to 4.9 mg kg^{-1}. The increased availability of Zn due to green manuring might be due to the mining of sub soil Zn. The behaviour of Cu in a green manured soil differs from that of Zn because there exist some competition for Cu between the adsorption on the oxides and soluble organic matter presumably with chelating ability. Copper may thus be present in soil solution at a higher concentration than Zn. Bijay Singh *et al*. (1992) observed that addition on gm to a flooded soil increased the DTPA extractable cu concentration by 1.5 fold through 12 week incubation period.

Weed control

Weeds cause significant reduction in crop yields if they are not controlled in time. The weed problem can be minimized to a greater extent through green manuring in the field into which crops to be grown. A field study was conducted at national research centre on weed science by Khankhare *et al*. (2002). The results of their study suggest that population and dry weight of weeds can be reduced identically with the use of dhaincha alone or integrated use of 60 kg n ha^{-1} through urea + 60 kg n ha^{-1} through dhaincha.

Disease control

Green manures can either provide organic matter to sustain microbial communities that suppress pathogens or the green manure may have a direct biocidal effect on the pathogen. Green manures may support microbial communities of bacteria, non-pathogenic *Fusarium species*, *Streptomyces* and other Actinomycetes. Eg. lucerne residues on common root rot of pea *(Aphanomyces eutieches)* (Williams-Woodward *et al.,* 1997), buckwheat against common scab *(Streptomyces scabies)* andverticillium wilt *of* potatoes (Wiggins & Kinkel, 2005).

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