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Mini Review

Cementing the Organic Farming by Green Manures

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Abstract

In this modern era of chemicals, the haphazard use of chemical fertilizers, pesticides, insecticides and weedicide is becoming a great concern. Accumulation and magnification of those toxic materials in soil is degrading soil health and also affects the human health indirectly. Hence, Agriculture is concentrating more towards organic, sustainable and eco-friendly measures of production. Provision of healthy organic products is a great challenge for modern agriculturist (Farmers). Organic farming relies on judicious use of FYM, Compost, Vermicompost, Green manures and several other factors. Green manures are organic sources for amelioration of soil physical, chemical and biological properties. Furthermore, Green manure conserves the soil available nutrients and suppresses the losses incurred due to erosion, leaching etc. Not only that, Green manure inhibits the several disease, pests and weeds.

Keywords: Green manures; Organic farming; Nitrogen contribution; Physical properties; Pest management

Introduction

Organic farming is an agriculture strategy of producing healthy food, soil, plants, environment and other biotic factors as a matter of concern. Simultaneously, avoiding the use of synthetically manufactured fertilizers, insecticides, pesticides and other growth regulating chemicals. It depends on use of biological fertilizer and managemental practices such as crop rotation, cover crops, green manures, legumes, crop residues, animal manures, off farm organic wastes and various aspects of biological pest control to improve soil quality and build soil organic matter parallelly controlling insect, pest, disease and weeds. The most popularly accepted definition of organic farming is: "Organic agriculture is a holistic production management system which promotes and enhances agro-ecosysem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system"

Green manuring is the process of raising crops and intentionally incorporating them in the soil at vegetative green stage or flowering stage. Green manuring is natural farming. Green manuring helps to improve the physical and chemical properties of the soil. Green manuring is method of substituting a basket of compost with handful of seeds. Generally, any non-woody plant can be used as green

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manuring crops. For instance, Sunn hemp (*Crotalaria juncea* L.), dhaincha (*Sesbania aculeata* L.), berseem (*Trifolium alexandrinum*), cowpea (*Vigna unguiculata*) and mungbean (*Vigna radiata*) are the commonly used green manuring crops**.** Green manuring crops can also be used as animal feed and in fiber production. Green manuring crops are incorporated in the soil when they are still green or soon after flowering. Continuous crop cultivation on a particular place for long period of time reduces the soil organic matter and affects the soil properties. Use of inorganic fertilizers, herbicides, pesticides deteriorates the soil physical, chemical and biological properties.

Nitrogen Contribution by Green Manures

Nitrogen is a prime macronutrient in charge of the vegetative development of plants. Plants contain 1-6% of nitrogen by weight and is essential for a various plants metabolic procedures. It is consumed by plants as NO_3^- (nitrate) and NH_4^+(ammonium) form and some of the time additionally in amide form. It is constituent of different metabolically dynamic compounds such like amino acids, protein, nucleic acids, purines, compounds and co-catalysts and alkaloids. Nitrogen in plants experiences a few compound catalyzed reactions producing NH_3, which gets assimilated into amino acids that are in this manner consolidated into proteins and nucleic acids. Nitrogen is a vital piece of porphyrin ring in chlorophyll, which converts light energy into chemical energy during photosynthesis. The rate uptake of nitrogen by plants at various development stage has high influence in the yield and yield attributing characters (Delogua *et al*., 1998).

Green manures, generally legumes contribute higher amount of nitrogen. They fix atmospheric di-nitrogen by symbiosis with rhizobia (*Rhizobium*, *Bradyrhizobium*, *Sinorhizobium* and *Mesorhizobium*). The legume rhizobium symbiosis compensates 40 percent of worlds fixed Nitrogen (Ladha *et al*., 1992). Nitrogen supply by all the green manures are not same, it depends upon the species and total biomass produced by it (Sullivan, 2003).It is reported that leguminous green manures can fix upto 80-100 kg of nitrogen with in a growth period of 45-60 days (Becker *et al*., 1995). The symbiosis of *Azolla-Anabaena* can fix 2-4 kg N/ha/day (Adhikary and Thakur, 2013). Green manure nitrogen is superior than urea nitrogen in growth and development of plants and increasing grain yield of crops (Singh *et al*., 1990). Nitrogen supply by green manures is not exigent in nature, it's a gradual and slow process. Green manuring crops not only fixes the atmospheric di-nitrogen but also aids in the conservation of nitrogen present in the soil. With the similar efficiency like that of mineral fertilizers, green manures furthermore improves the soil qualitative characters unlike mineral fertilizers that degrade the soil conditions (Becker *et al*., 1995b). Slower rate of nitrogen release by green manures prevents nitrogen losses by leaching, denitrification and NH_3 volatilization. Soil amended with green manures was found to have no NH_3 volatilization losses. HDRA (Henry doubleday research association) reported that winter green manures were effective for 'mopping up' excess nitrate in the soil. Grazing rye was particularly effective in reducing the leaching losses of nitrogen by an average of 95% in the trails conducted at HDRA. The segment of green-manure nitrogen accessible to a following harvest is typically around 40% to 60% of the aggregate sum contained in the green manuring crops. Green manure nitrogen contains two parts 'Fast N' and 'Slow N'. Fast N breaks down quick and is accessible to the plants promptly cropped and Slow N decays ease back and is accessible to the plants for quite a long while (Bouldin *et al*., 1988). Nitrogen demand of a crop and Nitrogen supply at adequate quantity and adequate time is a very great challenge for green manure dependent cultivation. Some green manuring crops along with their nitrogen contribution is presented in (Table 1).

Table 1: Major green manuring crops along with their Nitrogen contribution

Green manuring crops	Nitrogen contribution (kg/ha)	References
Crotalaria juncea	50-100	Lacsina *et al*., (1987)
Eichhornia crassipes	150-200	Dubey *et al*. 2015
Glycine max	115	Meelu *et al*.,1985
Cajanus cajan	33	Meelu *et al*.,1985
Sesbania aculeate	225	Meelu *et al*.,1985
Sesbania rostrata	176	Furoc *et al*., 1985
Vigna radiate	75	Meelu *et al*.,1985
Dolichos lablab	63	Meelu *et al*.,1985
Crotalaria juncea	169	Meelu *et al*.,1985
Sesbania rostrata	217	Ladha *et al*., 1988
Sesbania cannabina	171	Ladha *et al*., 1988
Cluster bean	91	Singh *et al*., 1991

Availability of Other Nutrients

Focusing primarily on nitrogen supply organic farming gets deviated away from phosphorus and potassium supply in the field. So the availability and loss minimization of these nutrients can be a matter of great concern and fruitful for organic farming. Green manures especially deep rooted, they absorb the nutrients from the deeper region and makes that available after its decomposition. The restoration of phosphorus (P) and potassium (K) in a proper and scientific way enhances the organic farming pattern (Talgre *et al*., 2012). Not only P and K other micronutrients such as sulphur, magnesium, zinc boron, molybdenum etc are also equally important.

Phosphorus availability is often decreased in calcareous and acidic soil due to binding with calcium carbonate and iron oxide (Von Wandruszka, 2006). Phosphorus release after decomposition is generally associated with phosphorus content in the green manure. Anonymous (2008) said that about 40 to 60 percent of phosphorus is released quickly after decomposition of plant biomass. In a organically managed system, mineralization of available organic phosphorus in soil is the prime source of phosphorus. Phosphorus present in the soil is to be made available to the plants (Oehl *et al*., 2001).Green manures incorporation to the soil is found to enhance the phosphorus cycle and increase the availability of sparingly soluble phosphorus (Cavigelli and Thien, 2003; Kamh *et al*., 1999). Green manure crops accumulate large amount of P and upon decomposition form bicarbonates (H2CO3). This bicarbonate can solublize soil mineral P and makes the phosphorus sufficiency for the succeeding crops (Sharpley and Smith, 1989; Tissen *et al*., 1994). During decomposition green manuring crops release and recycle the nutrients (nitrogen, phosphorus and potassium) in integrated plant nutrient management (Goyal *et al.*, 1999; Palaniappan, 1994; Selvi and Kalpana, 2009; Sharma and Ghosh, 2000; Singh *et al.*, 2007; Sinha *et al.*, 2009; Yadav *et al*., 2000). Addition of green manures increase the soil organic carbon subsequently leading forward to reduction on soil pH. This decrease in soil pH reduces the phosphate fixation in soil with iron and aluminium (Dey and Nath, 2015). Ultimately availability of phosphous increases. Lupins grown in phosphorus deficient soil were found to extrude protons and different organic acids (Shen *et al.*, 2005; Sas *et al.*, 2001). Green manuring uplifts the P uptake of succeeding crops by converting the fixed phosphorus into readily available forms (Cavigelli and Thien, 2003; Tisdale *et al*., 1985). P deficiency stimulates the formation of cluster roots in green manuring crops which are more active in P mobility and uptake (Sas *et al.*, 2001). In waterlogged conditions, green manures increased the availability of P through the mechanism of reduction, chelation and favourable alteration in soil pH. Higher availability of phosphorus from rock phosphate was reported due to green manuring in the rice fields (Cavigelli and Thien, 2003).

Green manure crops can fix up to 153 kg K/ha and up to 20 kg P/ha (Talgre *et al*., 2012). Dhaincha and green gram increased the soil available potassium by 3.7 and 2.4 per cent respectively (Dey and Nath, 2015). P and K utilization to an extent of 10 to 12 per cent was observed in field conditions due to green manure incorporation. Green manure crops contain appreciable amounts of NPK including other trace elements also (Bhuiyan and Zaman, 1996). They also mobilize S, P, Si, Zn, Cu, Mn and other nutrient element as a result of increased microbial activity (CO2 formation) and decreased redox potential (Becker, 1990). Green manuring with *Sesbania rostrata* increased both availability in soil and accumulation in plant of Fe, Mn and Cu due to the development of intense reducing condition, complex formation and greater nutrient holding capacity (Bhattacharyya and Mandal, 1996). (Eriksen and Thorup-Kristensen, 2002) found that cruciferous crops such as winter rape or fodder radish were particularly effective at preventing sulphur leaching into lower soil profiles. Green manures such as chicory accumulate large amounts of micronutrients including sulphur, boron, manganese, molybdenum, and zinc (Rumball, 1986). Green manuring crops promote mycorrhizal growth on the roots of succeeding crops, increasing soil phosphorus (P) and micronutrient availability (MacRae and Mehuys, 1985).

Effect on Soil Physical, Chemical and Biological Properties

Continuous crop cultivation on a particular place for long period of time reduces the soil organic matter and affects the soil properties. Use of inorganic fertilizers, herbicides, pesticides deteriorates the soil physical, chemical and biological properties. Green manuring has significant positive influence on soil physical (Bruce *et al*., 1990; Ebelhar *et al*., 1984), chemical (Ebelhar *et al*., 1984), and biological (Fageria and Baligar, 2005) properties. Green manures not only supply N or mulch in field but also improve soil physical and chemical properties (Becker *et al*., 1995a; Buresh and De Datta, 1991). Green manures helps in gaining back the deteriorated soil quality. Green manure primely accosts to the physical superiority of soil and parallelly focuses on chemical and biological properties also.

Physical Properties

Continuous use of same land for monocropping of bulky plants credits in the formation of hard pans, surface runoff, soil erosion, decreased water holding capacity etc. occurs. Green manure improves the soil physical properties in various ways. Soil organic matter is considered to be a heart of soil quality (Gregorich *et al*., 1994; Fageria, 2002) and also environmental quality (Fageria, 2002; Smith *et al*., 2000). A key function of green manures is the addition of organic matter to the soil. Green manures incorporated are readily decomposable and result in faster aggregate stability. Wani *et al*. (1994) found that addition of green manures and organic amendments in crop rotations provided a measurable increase in soil organic matter and other soil quality attributes compared with continuous monoculture cereal systems. Addition of organic matter by green manuring helps to stabilize the soil structure, increase the water holding capacity of the soil, increase the infiltration of water into the soil and percolation through the soil (Kumar *et al*., 2014; Raimbault and Vyn, 1991). Green manuring decrease bulk density and particle density, increase water stable aggregates, pore space, water intake and water retention (Bunch 1995; Husunjak *et al*., 2002; Pradit *et al*., 1993; Rahman *et al*., 2007; Sur *et al*., 1993; Triplett *et al*., 1968; Zerega *et al*., 1995). Green manuring on an average reduced soil bulk density by 5% and enhanced total porosity by 8% and macropores and large mesopores by 28% (Sultani *et al*., 2007). Sultani *et al*. (2007) observed that green manuring substantially increased the amount of available water to plants by 17% than the control. Green manures such as Lucerne, chicory, rye and red clover produce deep tap root systems which penetrate the compacted soil, stabilize the soil aggregates and increase pore size ultimately improving the seed bed structure (Schumann *et al.*, 2000). Furthermore, they produce root exudates which provide food for micro organisms, which in turn produce polysaccharide gum increasing the aggregate stability (Reid and Goss, 1981). Sesbania exhibits greater soil pore space in 1.5 to 15 µm radius range. Pores with diameters between 0.1 and 15 µm are assumed to retain more plant available water than larger pores. Schumann *et al.*, (2000) told that *Sesbania rostrata* and *Crotalaria juncea* improve the water holding capacity, prevent runoff and erosion, remove surface compaction and hard pan etc. Martens and Frankenberger (1992) reported that bulk density and aggregate stability are the major factors affecting water infiltration rates and plant available water. Furthermore, it prevents the soil erosion and improvement of soil surface condition. Green manures can also play an considerable role in minimizing soil erosion both by wind and rain (Cransberg and McFarlane, 1994). Erosion of soil by water is reduced as green manures acts as cover crops preventing splashing effect and losses by surface runoff. Wind erosion is reduced by increment in surface roughness, reducing the wind speed close to soil and holding the surface soil.

Chemical Properties

C/N Ratio

The C/N ratio is defined as the ratio of the mass of organic carbon to the mass of organic N in soil, organic material, plants, or microbial cells (Soil Science Society of America, 1997). Green manures, particularly legumes contain considerable amount of nitrogen and have relatively low C-N ratio (Bhuiyan and Zaman, 1996). So they avoid immobilization of available inorganic N during the decomposition period. Lower the C-N ratio faster is the decomposition of green biomass. Hence, considerable amount of soil organic carbon content was build up by the addition of green manures (Gurung and Sherchen, 1996; Kolar *et al*., 1993; Kumar *et al*., 1999; Ventura and Watanabe, 1993). The C/N ratio of green manure species influenced rice N uptake. Narrow C/N ratio of legume residue enhances soil N availability to plants (Beckie and Brandt, 1997; Beckie *et al*., 1997).

Soil pH

pH is the negative logarithm of the hydrogen ion concentration (more exactly the activity), or algebraically pH = $-\log_{10} [H^+]$ or pH= $\log_{10} 1/[H^+]$ (Sorensen). Addition of green manures in the soil decreased soil pH (Devasenapathy, 2010; Swarup, 1991) , Decrease in soil pH is due to the production of CO2 and organic acids by the decomposition of green biomass (Devasenapathy, 2010 ,Salahin *et al*., 2013) . Low pH favours availability of soil nutrients (Devasenapathy, 2010).

CEC

Cation exchange capacity (CEC) is a measure of the soil's ability to hold exchangeable cations and most importantly, an soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants. It is well known that organic matter has high CEC. Green manures amends soil with organic matter depending upon the biomass produced. Furthermore, It acts as a buffering agent against soil acidification. But it is to be noted that CEC is an inherent characteristics and cannot be altered significantly.

Biological Properties

Green manures stimulates soil microbial growth and activity, mineralization (Eriksen, 2005; Sikora and Stott, 1996), and increase soil fertility and quality (Doran *et al.*, 1988). Soil microorganisms degrade organic matter by the production of several enzymes and soil enzymatic activities are increased (Goyal *et al*., 1999; Kautz *et al*., 2004). Green manure provides nutrients rich in organic carbon for the microbial biomass and enhances biodiversity of soil micro-organisms resulting disease suppression, improvement in soil structure, improvement in soil properties and crop health (Campbell *et al*., 1991; Kumar *et al*., 2014; Schutter and Dick, 2001). Green manures applications can lead to significant increase in the amount of soil fungi, bacteria, and actinomycetes (Liu *et al*., 2006). Green manure application increased soil microbial biomass carbon and soil microbial biomass nitrogen by (1.94%–93.07%) and (2.30%–145.07%) (Xiefeng *et al*., 2014).Soil microbial biomass carbon and nitrogen is an important index to evaluate rhizosphere effect (Hu *et al*., 2006). Green manures can provide nutrition for the reproduction of soil microorganisms creating diversity and making the environment feasible for the new microorganisms yet to establish in that particular location. Green manure applications not only increased the amount of soil microorganisms, but also increased soil enzymatic activities due to root exudations and the efficiency of the transformation of soil nutrients, which are all beneficial and improve soil fertility.

Disease and Pest Management

On an average disease are assumed to do 1/3 rd loss of food grain from the total loss caused by various means like insects, weeds, rodents etc. Chemical pesticides, insecticides and seed treatment helps in the disease and pest management in a great extent but the integrated, eco-friendly and sustainable pest management techniques are often desired (Larkin and Griffin, 2007). Proper handling of green manures not only provides nutrition and organic matter sideways reduces the disease and pest infestation.

It is well known that green manures suppresses disease and pest incidence by different mechanisms which are yet to be understood fully. Primarily, green manure reduces the diseases by alteration in microbial communities. Green manure increase soil microbial activity (Davis *et al*., 1994), microbial diversity (Kumar *et al*., 2010; Lupwayi *et al.*, 1998), and density of microbes in soil. It provides favourable conditions for the well establishment of the microbial mass that suppress the malignant disease engendering pathogens. Once established well the microbial biomass suppresses the pathogen by phenomenas like competition, predation, parasitism, antibiosis etc. Furthermore, they increase the resistivity of plants. Significant reduction in *rhizoctonia* root rot of bean was observed due to green manure decomposition and rapid vegetative growth. Kumar (2010) found significant reduction in mycelial growth and sclerotia production by *Sesbania aculeata.* The application of rye-vetch green manures increased the soil microbial biomass *(Trichoderma, Pseudomonas)* and reduced the incidence of tomato southern blight significantly (Bulluck and Ristaino, 2002). Similarly, Direct biocidal effects have been observed in different green manures. They influence pathogen populations directly by the breakdown of glucosinolates (Charron and Sams, 1999) or by releasing fungitoxic compounds such as avenacin, saponins (Deacon and Mitchell, 1985; Engelkes and Windels, 1994), or allyl isothiocyanate (Mayton *et al*., 1996). Crucifers containing glucosinolates inhibits the fungal growth and *Pythium* spp. in particular (Lazzeri and Manici, 2001). Glucosinolates suppresses the plant parasitic nematodes and soil borne diseases also (Snapp *et al*., 2005). Furthermore, there are several instances of control of *Rhizoctonia solani* in vegetable crops (Villeneuve *et al*., 2004), verticillum wilt in strawberry (Francis Rayns and Anton Rosenfeld, Garden Organic), common scab management in potato (Wiggins and Kinkel, 2005) and sclerotinia wilt in lettuces (Pung *et al.*, 2005). *Sesbania rostrata* and *Aeschynomene afraspera* are often known for its ability to control *Hirschmanniella mucronata* and *H. oryzae* (Prot *et al.*, 1992). Green manuring improves the pathogen inhibition capacity. For example; streptomycetes which were collected from the green manured fields exhibited higher inhibitory effect (Wiggins and Kinkel, 2005).Rapeseed and hairy vetch grown together was found to be effective against nematodes *Meloidogyne incognita* and *Meloidogyne javanica*. Effects of nematodes *Meloidogyne javanica* and *M. incognita* were reduced to some extent by *Crotalaria* spp. (Germani and Plenchette, 2005). At the same time increased the mycorrhizal growth of fungi like *Glomus* spp. Green manures are found to be quite effective against several vegetable diseses like, lucerne hay against *Sclerotinia sclerotiorum* in lettuce (Asirifi *et al.*, 1994), lucerne residues on common root rot of pea (*Aphanomyces eutieches*) (Williams-Woodward *et al*., 1997) and buckwheat against common scab (*Streptomyces scabies*) and verticillium wilt of potatoes (Wiggins and Kinkel, 2005). Green manures serves as a host of some predators like carabid and staphalinid beetles (Andersen, 1997; Collins *et al*., 2003; Kajak and Lukasiewicz, 1994). Similarly, flowering green manures (crimson clover, buckwheat) attracts many predatory insects like, ladybirds, hoverflies, lacewings and parasitic wasps. Furthermore, Green manures acts as non-host plant. When cauliflowers were planted among other non-host plants, significant reduction (36-82%) in egg laying by cabbage root fly was observed.

Weed Management

Weeds are unit of agro-ecosystems that interfere with crop growth and development through competition and allelopathy and consequently reduce yield and quality of crops (Basstiaans *et al*., 2007). Weeds are not wrong plants they just are in wrong place. About 43% of crop yield loss was estimated worldwide when weeds were assumed to be uncontrolled.

The ultimate reason for growing green manuring crops are nitrogen contribution and mulching but sideways they are important for management of weeds too. Green manures involves various mechanisms for weed management. Firstly, green manures reduce weed infestation by disrupting cycles. Weeds seem to be adapted to a particular niche cycle if crops of same family are grown continuosly for long run (Blackshaw, 1994). Green manures adds rotation and narrows the opportunities for weeds to become adapted to that niche cropping cycle. Secondly, green manures exhibit allelopathic effect i.e. they release certain chemicals that inibit germination, growth and development of weeds. However, sideways it is to be noted that allelopathic effect of green manures depends upon the deposited plant material, soil characteristics, microbial population, micro-climate of the area and the diversity of the weed species in the area (Monquero *et al*., 2009). It is well known that crops with large seeds are relatively resistant than smaller seeds to allelopathic effect of green manures. Green manures like high glucosilinate varieties of brassicas (Nagabhushana, 2001), lucerne (Chung and Miller, 1995), crimson clover, vetch (Kamo *et al*., 2003), subterranean clover (Nagabhushana, 2001), red clover (Fisk *et al*., 2001) and yellow sweetclover (Guenzi and McCalla1962; McCalla and Duley 1948) exhibit allelopathic effect. Similarly, green manure supresses weed population by competing for light, water and nutrients. Also by the agronomic practices associated with growing a green manure suppress weeds like tillage, mowing, grazing and termination (Dowling and Wong, 1993; Norris and Ayres, 1991). After termination of green manures the residual green biomass prevents the entry of light and inhibits the germination of weed seeds. If managed well, proper termination of green manures can effectively kill almost all annual weeds.

Conclusion

Recent approaches of food security in world is misleading farmers to use maximum inputs (chemicals) for crop production. Haphazard use of synthetic fertilizers, pesticides, insecticides is deteriorating the soil characteristics and yield attributing parameters. In order to overcome this, Green manuring has emerged as a economic measure of supplement in farmers field instead of artificially manufactured chemical compounds. It is substituting a large portion in organic farming. Green manure can be used as mitigation measure for the recurring constraints present in organic farming practice. Green manure can mop up all the requirements (Physical, chemical, biological, pathological) of plants from their germination to fruiting.

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