World Journal of Agricultural Sciences 13 (3): 122-132, 2017
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2017.122.132

Impact of Green Manure Incorporation on Soil Properties and Crop Growth Environment: A Review

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Abstract: Green manuring is the process of turning of green plants into the soil either by raising them in same field or plants grown elsewhere at the green stage before flowering and incorporated into the soil.The green manure crops provide multifold advantages. Green manures add organic matter to the soil and recycle nutrients in to the soil. The nutrients are taken up by the green manure and held inside the plant. Legumes and other nitrogen fixing plants which take nitrogen from the air to the soil are particularly beneficial. The benefits of green manuring are generally interpreted as its capacity to produce or provide nitrogen as substitute for fertilizers. One of the major benefits of green manures is their ability to suppress weeds.Green manures help to stop the soil being carried away by wind and rain.The application of green manures to soil is considered as a good management practice in any agricultural production system because it stimulates soil microbial growth and activity, with subsequent mineralization of plant nutrients.

Key words: Green manuring · Soil fertility · Weed control and disease management

INTRODUCTION

Production of quality food grains in sufficient quantity forever growing population without damaging the soil quality, fertility and productivity is a one of the major challenges in the present agriculture scenario. The use of agrochemicals to enhance the agriculture production and to manage the agricultural pests is a common practice throughout the world. Now adays many farmers use these agrochemicals and pesticides in non-judicious manner leading to the loss of soil fertility and productivity and the negative impact on human health. The use of green manuring is the ray of hope in this context. The diverse green manure crops are present around the globe, which contribute to the soil nutrition dynamics and restore the soil health. Now, it is evident that green manure crops not only improve the soil health and fertility but it also helps to manage the agriculture pests.

Soil degradation is one of the major environmental concerns of today's world. Ever decreasing level of soil nutrients is posing threat to healthier food production for the ever increasing global population. Usages of inappropriate technologies have resulted in the deterioration of soil quality leading to soil organic matter losses and structure degradation, affecting water, air and nutrients flows and consequently plant growth [1]. For this reason, the application of organic matter including green manure to the soils has become a common environmentally important agricultural practice for soil quality restoration, maintaining soil organic matter, reclaiming degraded soils and supplying the plant nutrients[2]. Green manuring is the process of turning of green plants into the soil either by raising them in same field or plants grown elsewhere at the green stage before flowering and incorporated into the soil. Green manuring, defined by Pieters [3] as 'the practice of enriching the soil by turning under fresh plant material either in situ or brought from a distance' is a widely used practice in organic farming to maintain soil organic matter.

Green manure may be plant of grain legume such as pigeon pea, green gram, soybean or ground nut; perennial woody multipurpose legumes trees *viz., Leucaena leucocephala* (Subabul), *Gliricidia sepium* (Gliricidia or Mata Raton), *Cassia siamea* (Kassod tree) or non-grain legumes like sunnhemp (*Crotalaria sp*), dhaincha (*Sesbania spp*), Centosemia, Stylosanthes and Desmodium [4]. Sunnhemp (*Crotalaria juncea* L.),

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dhaincha (*Sesbania aculeata* L.), berseem (*Trifolium alexandrinum*) and mungbean (*Vigna radiata*) are most commonly grown as green manure crops. Leguminous crops like cowpea, mungbean, urdbean, pigeonpea, chickpea, lentil, field pea, lathyrus, rajmash, temphrasia, groundnut, soybean, woody legume (eg. *Leucaena, Gliricida, Pongomia* and *Delonix*), dhaincha (*Sesbania sp*.) and sunnhemp (*Crotalaria sp*.) have ability to fix the atmospheric nitrogen in their root nodules. Green manuring had been widely practiced in Asia but in the last few decades with the increased pressure for food production to feed ever growing global population and availability of readily available low cost chemical fertilizers, the interest in green manuring had decreased. However, with increase in soil problems due to non-judicious use of agrochemicals, increased fertilizer costs and the public concern for pollution and conservation of energy, green manures have again become important both to researchers and low input farmers in particular. Hence, there have been renewed research efforts during the last two to three decades on green manures [2].

Advantages of Green Manuring: The green manure crops provide multifold advantages which can broadly be grouped as greater soil fertility. Green manures add organic matter to the soil and recycle nutrients in to the soil. They help prevent nutrients being washed out of the soil. The nutrients are taken up by the green manure and held inside the plant. Legumes and other nitrogen fixing plants which take nitrogen from the air to the soil are particularly beneficial. The benefits of green manuring are generally interpreted as its capacity to produce or provide nitrogen as substitute for fertilizers. Green manures, particularly the legumes have relatively more N, low C**:**N ratio and behave almost like chemical nitrogenous fertilizers [5]. This helps to increase crop yields keeping the use of chemical fertilizers at low level. Higher availability of phosphorus from rock phosphate has been reported in rice due to green manuring [6]. Green manures crops during decomposition release nutrients and involve in recycling the nitrogen, phosphorus and potassium in integrated plant nutrients system (IPNS)[1].

Buresh [7] reported that the highest grain yield and biomass were recorded by the combined applications of green manure with urea (80 kg N ha^{-1}). Bhuiyan and Zaman [8] noted that green manures, particularly the legumes have relatively more N, low C**:**N ratio and behave almost like chemical nitrogenous fertilizer. Bokhtiar and Sakurai [9] reported that the application of organic manure in combination with chemical fertilizer increased absorption of N, P and K in cane leaf tissues both in the plant and ratoon crop as compared with chemical fertilizer alone. This led to higher cane and sugar yield of both crops. Bokhtiar [10] reported that the green manures and the supplemented urea increased cane yield upto 57% along with the significant increase in organic matter, total N and available P & S of the soil. Ambrosano [11] reported that the biomass of sunnhemp induced a complete N substitution in sugarcane and could positively affect yield and increase $Ca^{2+}$and Mg^{2+} contents, sum of bases, pH and base saturation and decrease potential acidity as well as increase profit. The combination of inorganic fertilizer and green manure resulted in higher sugarcane yields than either N source separately. The recovery of N from ammonium sulfate was higher in the first year whereas in the green manure presented a longer residual effect and resulted in higher yields of cane in the second cycle.

Hemalatha [12] noted that amongst the organic treatments, *insitu* incorporation of daincha @ 12.0 t ha^{-1} recorded taller plants, higher number of tillers per hill, leaf area index and dry matter production, grain yield and straw yield of rice over no manuring. Hiremath and Patel [13] reported that incorporation of either of the three green manure crops *S. rostrata, S. aculeate or C. juncea* was comparable with that of 100 kg N ha^{-1} for grain yield of 5 ton/ha during summer at Navsari (Gujarat).

Maiksteniene and Arlauskiene [14] reported that the yield of spring wheat was 2.12 mg ha^{-1} on unfertilized soil, whereas red clover and hybrid Lucerne, as a preceding crop gave a wheat yield of 3.46 mg ha^{-1} and 3.57 mg ha^{-1}, respectively. Green manuring in the absence of N fertilizer decreased the mustard yield. But the combined application of green manure at 100 kg N ha^{-1} further improve the yield potential of mustard, illustrating the benefit that any amount of fertilizer N cannot achieve. Green manuring to mustard substantially improved the yield of the succeeding crop of rice. Mandal [15] noted the higher yields of rice as well as succeeding wheat crop in *Sesbania* green manures. Parihar[16] noted that grain yields obtained with 80 kg N ha^{-1} (50% through green manure + 50% through urea) were comparable to 80 kg N ha^{-1} (50% through FYM + 50% through urea), but both were significantly superior over 80 kg N through urea. Patro [17] noted the highest total productivity of rice-wheat with *Sesbania* green manure along with 180 kg N ha^{-1} applied to rice and 150 kg N ha^{-1} applied to wheat in sequence.

Improving Soil Structure: Green manures improve soil structure, letting more air into the soil and improving drainage. Green manures help sandy soil hold more water and not drain so quickly. The regular use of green manuring results in a high organic matter reserve which enhances both soil chemical and physical properties when compared to control fields. In addition, usages of green manures between crop sequences enhance the effectiveness of nutrient recycling, since a regular pruning strategy increases the soil organic matter and other nutrients. Enhanced soil qualities of cultivated lands reflect by higher crop yields [18].

Guled [19] noted the *in-situ* incorporation of sunnhemp in *Rabi* sorghum–Sunflower yearly rotational cropping system increased the infiltration rate from 2.8 (Farmers practice) to 3.9 cm/hr decreased the bulk density from 1.18 mg/m^3 control) to 1.0 mg/m^3 increased the percent pore space by 6.5 percent, maximum water holding capacity by 5.5 cm/ha, improved hydraulic conductivity by 1.0 cm/hr and water stable aggregates by 5.40 percent. Annabi [20] reported that the amount of decayed organic matter found at the soil surface can also enhance infiltration. Soil organic matter can increase by application of organic fertilizer such as green manure and animal manure. Ray and Gupta [21] noted that incorporation of green manure before puddling of rice field improved soil aggregation and there by decreased bulk density. Thakur [22] noted that significant decrease in bulk density of silty clay loam soil at Palampur due to incorporation of dhaincha (*Sesbania aculeata*) and french bean biomass at an average rate of 18.3 and 1.3 t ha^{-1} $year^{-1}$ after every 3 years, respectively.

Prevention of Soil Erosion: Green manures help to stop the soil being carried away by wind and rain. The roots penetrate the soil and hold it in place. Mono culture of crops e.g. sugarcane resulting in the effects included the formation of hard pans, decreased water holding capacity, surface compaction, runoff and erosion can be reclaimed or improved using green manure crops *viz., Sesbania rostrata* and *Crotalaria juncea* [23].

Weed Control: One of the major benefits of green manures is their ability to suppress weeds [24]. Green manuring enriches diversity of the rotation and reduces the opportunities for weeds to become adapted to a particular cropping pattern. Some green manures also secrete specific chemicals into the soil (both during their life and after incorporation) that inhibit weed seed germination. This 'allelopathic effect' is demonstrated by many clovers but also non legumes including rye. Bare soil can become quickly overgrown with weeds which can be difficult to remove. Green manures cover the ground well and stop weeds growing beneath them, by competing for nutrients, space and light.

Increase in Microbial Biomass and Activities: The application of green manures to soil is considered as a good management practice in any agricultural production system because it stimulates soil microbial growth and activity, with subsequent mineralization of plant nutrients [25].

Leguminous and non-leguminous plants are used as green manures. Leguminous green manures can fix large quantity of atmospheric N_2 and can provide useful amounts of organic matter in soil. Non leguminous green manures only can increase the organic matter in soil and do not fix atmospheric N_2[26].

From the microbiological point of view, green manure has the following two main positive effects:

- It provides nutrients rich in organic carbon for the microbial biomass which converts unavailable nutrients in plant residues to ones available for the crops.
- It enhances biodiversity of soil microorganisms. These positive effects on soil microbial populations can be increased by inserting different green manure selections in crop rotation programs.

Green manures and other organic matter (OM) amendments have been used to improve soil tilth and fertility since early times. Increase in beneficial microbial activity is often related to increase in organic matter. Organic matter is vital as a food source and heaven for beneficial microorganisms that are related to disease suppression, soil structure, improvement in soil properties and crop health [27]. The use of green manures in between successive crops helps maintain or increase organic matter in soils [28].

Green Manuring and Soil Health Dynamics:Green manures have become a vital approach particularly in the area of sustainable agriculture. One of the most important green manure crops dhaincha (*Sesbania aculeata* L.) upon its incorporation in the soil at succulent stage adds 60-90 kg N h^{-1} [29] and helps to improve the physical and biochemical structure of the soil, prevent leaching losses of nutrients, enhancing water holding capacity, preventing weed growth, reducing residual effect of

chemicals and also helps in reducing the soil borne inoculum of phytopathogens [2]. Green manures upon its decomposition not only add to the organic matter of the soil but are also good sources of mineral nutrients required by the crop plants grown in the field. Decomposition of green manures serves major functions for microflora by providing energy for their growth and supplies carbon for formation of new cell material to soil biota which colonize saprophytically on the decomposing litter. During decomposition a series of biochemical changes takes place which ultimately lead to the simplification of various compounds. The nutrients released by decomposers are incorporated into the soil which improves the status of soil fertility and recycled into the living organism. The use of green manure crops facilitating the reduction of soil borne diseases; suppress the weeds and other pests getting emphasis because of its sustainable and environmental friendly nature. Thus the green manuring helps the promotion of organic crop cultivation [30].

Jayapaul [31] studied the influence of population and stage of incorporation of intercropped green manure (Dhaincha) and nitrogen levels on yield and quality of sugarcane. The effects of green manuring with dhaincha and sunnhemp in combination with different dosages of urea (Nitrogen) on the productivity of subsequent sugarcane crop and the fertility of the soil were examined by Bokhtiar [10]. They reported that the green manures and the supplemented urea increased cane yield upto 57% along with the significant increase in organic matter, total N, available P and S of the soil. Kumar and Prasad [32] investigated integrated effect of mineral fertilizers and green manure on crop yield and nutrient availability under Rice-Wheat cropping system. They found that green manuring and green gram residue incorporation enhanced the uptake of N, P and K by rice and wheat. They recorded significant buildup of organic carbon, available N, P and K in soil under graded levels of fertilizers and also with green manure and green gram crop incorporation after the picking of pods.

Lokesh Dubey [33] reported that green manures improve soil structure, letting more air into the soil and improving drainage. Organic matters help 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. Change in chemical property of soil could be clearly observed. Leguminous green manure crop in soil increases nitrogen level by fixation. Increase in Fe and Mn concentration can be seen under submerged condition. Different green manures and grain legumes are used to increase the nitrogen content and texture of the soil.Among the green manures *Sesbania aculata* accumulated the largest amount of biomass and nitrogen contribution and among the grain legumes, cowpea ranks first both in terms of grain yield and biomass addition.

Nutrient Cycling and Green Manuring:A large number of soil microorganisms exist in the soil as long as there is a carbon source for energy. Soil inhabiting microorganisms are very critical for decomposing organic residues and recycling soil nutrients. The addition of green manure or other organic matter helps in the increase of microbial biomass. The process of decomposition is of great significance because unless the energy and nutrients are released through microbial activity the primary product cannot exist for long time. Soil contains five major groups of microorganisms'*viz.,* bacteria, actinomycetes, fungi, algae and protozoa along with other members of animal kingdom such as, nematodes, earth worms and arthropods. These microorganisms play an important role in cycling of mineral nutrient from plants tissue bulk to plant tissue via herbivore, carnivore and saprophagous food chain. Decomposition is a process of great significance which changes the distribution and population dynamics of soil microorganisms [34].

Bah [35] have studied the phosphorus uptake from different green manures and phosphate fertilizers in an arid tropical soil. They reported that the green manure crops markedly increased fertilizer Phosphorus utilization in combined treatments from 3 to 39%. Sinha[1] studied release of nutrients *viz.,* N, P & K bound in litter of decomposing green manure crop *Crotolaria juncea* in relation to different climatic factors. They reported temperature and moisture dependent release of different nutrients into soil from green manure residue. Brar and Sidhu [36] studied the effect of soil water on pattern of release of NH_4-N and NO_3-N during decomposition of added green manure residue in the laboratory conditions. They suggested that NH-N accumulation increased significantly with decrease in soil water but the release of NO_3-N decreased. Soil temperature has the effect on pattern of nitrogen release during decomposition of added green manure residue in soil.Magid [37] reported higher nitrogen mineralization at low temperature during their studies on the decomposition of green maures*viz*., *Medicago lupulina* and *Melilotus alba*.

Abeysekerra [38] noted that organic manures enhanced the mineral nitrogen contents in the soil irrespective of the source of green manure.

EichlerLobermann [39] noted that after decomposition, the 7organic P & K bound in the green manure crop may provide an easily accessible form of P & K to succeeding crops. Chaphale [40] noted the green manuring has been reported to increase the organic carbon, available N, P and K status of soil in highly sodic soils. Mahapatra [41] reported that maximum dry matter production was recorded in *S. aculeata* green manuring (60 kg N ha^{-1}) plus Azolla inoculation (30 kg N ha^{-1}). Nair and Gupta [42] stated that *Sesbania* green manure incorporation in rice also increased the N, P & K uptake by rice and succeeding wheat crop over control. Pattanayak [43] noted the recycling of K through daincha, azolla and sunnhemp varied from 10.0 to 17.5, 11.7 to 15.9 and 2.7 to 3.0 kg ha^{-1}, respectively. Pandey [29] noted that *Sesbania aculata* upon its incorporation in the soil at succulent stage adds 60- 90 kg N ha^{-1}. Singh and Chauhan [44] reported that organic carbon and available N, P & K contents in soil were also improved with the application of FYM and Kudzu (*Pureriathumbergiana*) compost in wheat-ragi sequence under Almora conditions.

Green Manuring and Soil Borne Diseases: The management of soil borne plant pathogens is particularly complex because these organisms live in or near the dynamic environment of the rhizosphere and can frequently survive long periods in soil through the formation of resistant survival structures. Soil borne pathogens are responsible for crop yield losses in many plants [45]. Increasing restriction on the use of agrochemicals is motivating development of ecologybased cropping systems, including green manures, to manage soil borne diseases. Organic soil amendments including green manures (GMs) have been studied as a potential control strategy for soilborne diseases.

Effect of Green Manuring on Fungal Diseases: For soil borne diseases, chemical fumigants and seed treatments can provide control up to some extent, but they are not always practical or effective and integrated, sustainable disease control options are always desirable [46]. It is well established that the practices of green manuring not only provides a number of nutrients and organic matter to plant at very cheap cost but also reduces the disease incidence caused by several soil borne plant pathogens. Control of soil borne fungal diseases through organic amendment including green manuring has been observed by several workers [47].

The rhizoctonia root rot disease of bean was reduced by the decomposition of green plant materials and due to the effect of accelerated growth of associated microflora for the management of soil borne plant diseases caused by *Sclerotinia spp.* Brassica green manure crops was used by Pung [28]. They suggested that besides the soil improvement the Brassica green manure crops have the potential to minimize the inoculum density by virtue of their ability to produce different types and levels of biofumigant chemicals, collectively known as isothiocyanates (ITCs). The green manure crops specially crucifers containing Glucosinolates inhibits the population of *Pythium spp.* in particular and total fungal population in general [48]. The addition *Lycopersicon esculentum* of organic residues to soil is an option to control some soil borne diseases. Blum and Kabana [45] recorded less incidence of germination and formation of sclerotia and reduction in mycelial growth of Sclerotium rolfsiiafter amendment with plant parts of kudzu, velvet bean and pine bark along with benzaldehyde in soybean and tomato. They recorded that the colonization of sclerotia by *Trichoderma sp* was increased after the amendment. The numbers of soybean (*Glycine max*) plants were recorded higher and diseased plants were lower than the non-amended soil. Disease severity on tomato plants was low in soil treated with kudzu or velvet bean and pine bark.

The effect of green manuring with *Sesbania aculeata* L on three potential soil borne plant pathogens viz., *Rhizoctonia solani*, Sclerotium rolfsiiand *Sclerotinia sclerotiorum* has been studied during the decomposition of *Sesbania aculeata* L in soil [2]. He found significant reduction in mycelial growth and sclerotia production of these soil borne pathogens. Ochiai [49] studied green manuring effects on soil quality in relation to suppression of Verticillium wilt of potato, three green manure types (Austrian winter pea, *Pisum sativum* L., Broccoli, *Brassica oleracea* L., or Sudan grass, *Sorghum vulgare*) were incorporated at different rates. Inoculum density was reduced relative to the non-amended and wilt severity was reduced approximately 70% by all green manures applied @ 24 mg ha^{-1} and 74% by Austrian winter pea applied @ 12 mg ha^{-1}. Tuber yield was reduced approximately 20% in non-amended, *V. dahlia* infested controls relative to the non-infested controls. One potential alternative to fumigation is the plough down of green manures, or the

incorporation of other organic soil amendments, to create soil conditions that are suppressive to the disease. Various types of green manures *viz.,* Austrian winter pea, broccoli, Sudan grass, barley, or corn [50] have been shown to reduce the severity of Verticillium wilt of potato. The addition of fresh green manures into soil influences the saprophytic growth of *Rhizoctonia solani* and thereby affects the damping off disease in Canola [51].

Larkin and Griffin [46] used Brassica crops including canola, rapeseed, radish, turnip, yellow mustard and Indian mustard in crop rotations and as green manures and found these crops associated with reductions of soil borne pathogens and diseases of potato at different level *viz.,* culture in laboratory condition, in greenhouse trials and in field trials on commercial potato farms. Various serious pathogens *viz., Rhizoctonia solani*, *Phytophthora erythroseptica*, *Pythium ultimum*, *Sclerotinia sclerotiorum* and *Fusarium sambucinam* were found nearly completely inhibited in *in-vitro* condition with Indian mustard (80-100%). Similar results were observed in greenhouse trials and in field trials. Sunnhemp (*Crotalaria juncea* L.) reported that green manure during its decomposition reduces the soil borne pathogens [47]. Yadava [52] found significant reduction of sclerotia and mycelia of the test pathogens in his investigations. He recorded *Trichoderma harzianum*, *Gliocladium virens*, *Aspergillus niger, Penicillium citrinum* and *Curvularia lunata*, the most effective fungal decomposers of *Crotalaria juncea* L. against *Sclerotium rolfsii* and *Rhizoctonia solani*. Kamil [47] have also studied the effect of green manuring of *Crotalaria juncea* L. on soil borne pathogens and found the similar results.

Manici [53] investigated the effect of green manure on *Pythium spp*. population and microbial communities in intensive cropping systems and observed that green manure is useful to reduce the saprophytic and pathogenic population of *Pythium spp* whereas on the other hand it promotes beneficial microbial communities in the soils. Cultivation of oat and its incorporation in soil helps in reduction of hyphae, zoospores and oogonia of *Aphanomyces cochlioides* due to its saponin [54]. The application of rye-vetch green manure in soil has significantly reduced the incidence and disease severity of tomato southern blight pathogen *viz.,* Sclerotium rolfsiiand increased the propagules of beneficial microbes e.g. Trichoderma and fluorescent Pseudomonas etc. in soil amended with rye vetch green manure and other organic amendments [5].

Effects of Green Manuring on Phytobacterial Diseases: The green manure incorporation reduces the severity of several bacterial diseases [55]. Cardoso [56] evaluated effects of incorporation of freshly cut aerial parts of pigeon pea (*Cajanus cajan*) and crotalaria (*Crotalaria juncea*) on control of tomato bacterial wilt. Both plant materials were used in concentrations of 10, 20 and 30% (v/v), into soil infested with *Ralstonia solanacearum* and the soil was incubated for 30 and 60 days before planting. The wilting symptoms and percentage of flowering plants were evaluated at 45 days. All evaluated concentrations with incorporation and incubation for 30 days of aerial parts of pigeon pea and Crotalaria controlled 100% tomato bacterial wilt. Green manures and crop sequences influence potato diseases and pathogen inhibitory activity of indigenous Streptomycetes. Wiggins and Kinkel [57] evaluated Green manures *viz.,* buckwheat and canola in conjunction with three crop sequences (alfalfa-potato, corn-potato and potato-potato). Compared with fallow controls, tubers grown in buckwheat treated soil had significantly lower Verticillium wilt ratings and tubers grown in buckwheat or canola treated soil had greater yields. Potatoes grown in soil planted to corn or alfalfa the previous year had significantly lower Verticillium wilt and potato scab ratings as well as higher yields than potatoes grown in soil previously planted to potato. Streptomycetes of soils collected from green manure treated plots tended to have greater *in vitro* pathogen inhibitory activity than streptomycetes from fallow treated plots.

Effects of Green Manuring on Phytopathogenic Nematodes: Green manure crops are helpful to reduce nematodes in soil in addition to reduction in soil borne pathogens. Green manure has been used to promote biological control against nematodes of agricultural crops [58]. Two leguminous green manure crops *viz., Sesbania rostrata* and *Aeschynomeneafr aspera* were successfully used for the control of *Hirschmanniella mucronata* and *H. oryzae* in irrigated rice system. Most of the research on *Crotalaria* has focused on nematode suppression in agricultural production systems. Crotalaria is a poor host to many plant parasitic nematodes including *Meloidogyne spp., Rotylenchulus reniformis, Radopholus similis,*

Belonolaimus longicaudatus and *Heterodera glycines*. It is also a poor or non-host to a large group of other pests and pathogens is competitive with weeds without becoming a weed, grows vigorously to provide good ground coverage for soil erosion control, fixes nitrogen and is a green manure [59].

Incorporation of green leaf manures *viz.,* Potria (*Thespesia populnea*), Calotropis (*Calotropis gigantia*), Neem (*Azadiracta indica*), Gliricidia (*Gliricidia maculata*) and Glycosmis (*Glycosmis pentaphylla*) helps to reduce most serious Root knot nematode (*Meloidogyne incognita*) in tomato [60]. *Crotalaria spp*. can be used as pre crops for providing green manure while at the same time decreasing the level of detrimental nematodes *viz., Meloidogyne javanica* and *M. incognita* and increasing the level of beneficial mycorrhizal fungi *Glomus sp*. [61].

The green manuring crops reduces the several nematodes vectors viz., Trichodorid nematodes *viz., Paratrichodorus teres*, *P. pachydermus* and *Trichodorus similis* of Tobacco Rattle Tobravirus (TRV) which can infect several ornamental bulb crops. Household waste compost and spent mushroom compost in combination of green manure crops *viz.,* Italian rye grass, white mustard and fodder radish were evaluated against nematode transmitted TRV [62]. They reported reduced infection rate of Tobacco rattle virus in the plants during the first growing season but not of the plants grown from the corms in the next year. Desaeger and Rao [63] noted that *Crotalaria juncea* was used as a preplant cover crop; it suppressed population growth of most plant parasitic nematodes except *Pratylenchus spp*. and *Helicotylenchus* spp.

Green Manuring and Suppression of Plant Diseases-Mechanisms: The mechanisms by which green manures may suppress or influence diseases are varied and often unknown. Green manures may influence pathogens directly through the breakdown of glucosinolates [64] or by releasing fungi toxic compounds such as avenacin, saponins or allylisothiocyanate [65]. Green manures may also affect soil borne pathogens indirectly by influencing indigenous microbial populations [66]. For example, incorporation of soil amendments has been shown to increase soil microbial activity, microbial diversity and density of microbes [67] in soil. These changes in the microbial community may affect pathogen populations through competition, parasitism, predation or antagonism [68]. Enhancing the pathogen inhibitory activities of the indigenous soil microbial community, specifically offers a potential alternative for plant disease control. The amended soil may be less conducive to pathogen germination or growth, more optimal for the host resulting in healthier plants that are less susceptible to the pathogen. The addition of green manures may affect the disease incidence variably [69].

The effect of mustard green manuring on black scurf, white mold and powdery scab disease in potato was evaluated by Sexton [69]. They found decreased incidence of black scurf, incidence of white mold disease increased on leaves and stems in following potato crop whereas no effect was recorded on the incidence of powdery scab disease. In some cases of OM mediated suppression of disease severity was associated with reduced inoculum density [50]. In other cases, suppression was independent of changes in soil population of the pathogen [70], suggesting that different mechanisms may be relevant for different amendments [71]. The few studies that explicitly investigated changes in soil microbial properties following organic soil amendments in relation to diseases severity [72] indicated a correlation between increased microbial activity and reduced diseases severity. The use of non-coposted organic amendments, including high nitrogen materials and manures and green manures or ‘tarping’, for suppressing soil borne diseases has been studied by various workers. Though Green Manures offer substantial benefits to the soil including increased organic matter and nutrients, improved soil structure, better weed and erosion control [24], disease control through the use of GMs is sometimes considered to be inconsistent [70]. The inconsistent results among these studies likely reflect the varying conditions and circumstances under which the experiments were conducted, including the use of diverse Green Manure species, different soil types and crop cultivars, varying pathogen inoculum densities and the use of naturally versus artificially infested soils.

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