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AGRONOMY

Farmyard Manure: A Boon for Integrated Nutrient Management

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ABSTRACT

In the present review, farmyard manure is explained as a perfect source of nutrients for plant growth as well as for soil microbiota. It is one of the efficient and effective organic manures. It can provide organic matter to soil microbes as a source of carbon. An increase in microbial population leads to the degradation of pesticides and heavy metals to less harmful compounds. In addition to it, ions of harmful elements get adsorb on organic colloids and become immobile in soil. Application of farmyard manure not only increases the availability of nutrients in the soil but also improves the soil properties like soil structure, water holding capacity, bulk density, cation exchange capacity, etc. Studies revealed that farmyard manure is an excellent organic manure for sustaining good soil health along with achieving desired food production.

Highlights

- Farmyard manure is an effective and efficient source of nutrients to soil microorganisms as well as to plants comparative to all other manures.
- Farmyard manure plays an important role in the remediation of pesticides, herbicides, and heavy metals along with increasing nutrient supply in the soil.
- Apart from improving nutrient content, farmyard manure also improves soil's physical, chemical, and biological properties.

Keywords: Farmyard manure, plant growth, biocontrol agent, sustainable farming, soil health

Inorganic fertilizers use escalated tremendously in order to fulfill growing food needs for last three decades. Excessive chemical fertilizers application leads to soil, water, and air pollution. Overuse of fertilizers affects the soil health through an adverse change in soil organic matter, soil microbial population, and ultimately soil reaction (Erisman *et al*. 2008). On the other hand, excess use of fertilizers deteriorates surface water reservoirs as well as groundwater as fertilizers are removed through leaching and surface runoff from crop fields. Chemical fertilizers mainly containing nitrogen in various forms result in air pollution through the release of nitrogen oxides (NO, N_2O, and NO_2) (Byrnes 1990). Excessive inorganic fertilizers use also leads to their build-up in plants that ultimately affect human health (Savci 2012).

In general agriculture, the use of chemical fertilizers cannot be ruled out completely, but balanced fertilization is expected to diminish the environmental concerns while sustaining a strong

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food-producing capacity (Wu and Ma 2015). On the other hand, farming totally based on the use of organic nutrient sources is a better option for maintaining soil health, but it has a drawback, i.e., low productivity. So, an INM seems like an appropriate approach to maintain soil fertility along with sustained crop production. Manure is an organic material, generally obtained from animal excreta except in case of green manure, which is basically of plant origin and it can be used as organic source of nutrients in soil (Wu and Ma 2015). These are comparatively cheap and eco-friendly inputs. These have huge potential for maintaining nutrient supply, which can reduce the dependence of farmers on chemical fertilizers use. Farmyard manure has been used for centuries as a fertilizer for farming. FYM helps in improving soil structure and soil biomass (Dauda *et al.* 2008). FYM also help in improving soil physical properties. It also improves the chemical properties of the soil by increasing soil organic carbon, nitrogen, phosphorus and potassium content in the soil (Bayu *et al.* 2006). Therefore, reducing the use of synthetic fertilizers and to conserve the natural resources while sustaining crop production are major issues in the present, which is only possible through adoption of nutrient supply system that involves integrated use of nutrient sources (Merentola *et al.* 2012). The use of organic manures in combination with chemical fertilizers offers a great opportunity to increase yield and soil productivity (Wu and Ma 2015).

Farmyard Manure (FYM) Nutrient Composition

Dry litter in sufficient quantity, which is spread under cattle shed for urine absorption, is required for FYM preparation. Collect the materials from trenches, pits or heaps consisting of dung and urine-soaked litter.

In India, a major portion of cattle dung is being converted into dung cake and used as fuel by farmers. Major portion of the cattle dung and urine get wasted through urine soaking into the earthen floor of the cattle shed. Continuous exposure of FYM to the hot sun and heavy rain result in loss of nutrients in the form of ammonia (Webb *et al.* 2004).

Cattle dung is rapidly decomposed by high temperatures when the complex organic form of nutrients contained in them are converted to simple inorganic forms of nutrients, which are washed down by high rainfall (Reddy *et al.* 2010).

Table 1: Nutrient composition of farmyard manure (Chahal *et al*. 2019)

Nutrients	Content
N	0.87 %
P	0.49 %
K	0.77 %
S	0.42 %
Ca	47.43 mg kg^{-1}
Mg	16.81 mg kg^{-1}
Zn	15.43 mg kg^{-1}
Cu	2.97 mg kg^{-1}
Fe	67.83 mg kg^{-1}
Mn	103.84 mg kg^{-1}

Microorganisms in Farmyard Manure Treated Soils

The bacterial isolates present in farmyard manure belong to genera *Pseudomonas*, *Bacillus*, *Pseudomonas*, *Azotobacter*, *Flavobacterium*, and *Corynebacterium*. Apart from it fungal isolates that were discovered from FYM belongs to the species like *Rhizopus, Aspergillus, Penicillium, Trichoderma and Mucor* (Adebusoye *et al.* 2007; Akinde and Obire 2008; Umanu *et al.* 2013).

Main Features of FYM

1. Incorporation of FYM in the soil and its subsequent decomposition results in enhanced organic carbon content of the soil.
2. Application of FYM into soil increases organic carbon stock. Soil organic matter (SOM) has a large number of exchange sites that ultimately result in higher cation exchange capacity (Laxminarayana 2001; Verma *et al.* 2010; Scotti *et al.* 2015).
3. Organic anions released from FYM retard the phosphorus fixation in soil by complexing with organic ligands and chelation of it with cations like Ca, Mg, Fe, Al, Zn, Mn and Cu (Singh *et al.* 2015). Moreover, the nutrient agents such as humic and fulvic acids produced during the decomposition of organic manures increased mobility, solubility, and availability of nutrients (Kaushal and Kaushal 2013).

Table 2: Major fungi found in organic soils and their functions

Sl. No.	Fungi	Benefits	References
1	*Acaulospora elegans*	Arbuscular mycorrhizal associations	Kamble *et al.* 2018
2	*Aspergillus niger*	Breakdown of plant lignocelluloses	Gautam *et al.* 2011
3	*A. nidulans*	Remediation of arsenic in soil	Maheswari and Murugesan 2009
4	*A. terreus*	Storehouse of several anticancer bioactive compounds	Nadumane *et al.* 2016
5	*F. moniliforme*	Source of mycotoxins	Bacon and Hinton 1996
6	*Penicillium rubrum*	Cellulose degradation	Swer *et al.* 2011
7	*Trichoderma lignorum*	Act as a parasite on pathogenic fungi	Schuster and Schmoll 2010

Table 3: Major bacteria found in organic soils and their functions

Sl. No.	Bacteria	Benefits	References
1	*Pseudomonas fluorescens*	Plant growth-promoting rhizobacteria and bio-pesticide	Ganeshan and Kumar 2005
2	*Pseudomonas putida*	Bio-control or Bioremediation	Zhou *et al.* 2019
3	*Bacillus megaterium*	Increases plant growth and resistance against salt stress	Trivedi and Pandey 2008
4	*Bacillus pumilus*	Increases nutrient availability in soil	Masood *et al.* 2019
5	*Bacillus coagulans*	Uses as phosphorus biofertilizer	Yadav *et al.* 2012
6	*Azotobacter vinelandii*	Aerobic nitrogen fixation	Van Dommelen and Vanderleyden 2007

4. Organic acids produced from FYM result in the release of Ca from exchangeable sites (Ano and Ubochi 2007).
5. Chelation between organic compounds and metals blocking sorption of micronutrients increases their concentration in soil solution (Madrid 1999; Cline *et al.* 1982) reported that organic acids like citrate, oxalate, malate, malonate, and succinate could all act as chelators of micronutrients; as a result, nutrient availability get increases.
6. Combined application of FYM with fertilizers increases the absorption of nutrients which enhances cell division, cell elongation and thus increased the metabolic activity of plants (Torrey 1950).

Role of FYM in Heavy Metal Reduction

Waste water from industries is a common source of toxic heavy metals pollution that cause various health problems (Mohan and Gupta 2014). Chromium (Cr), copper (Cu), lead (Pb),cadmium (Cd), mercury (Hg) etc. are numerous metals that posses toxicity to environment (Meena *et al.* 2008).

Electrolytic deposition, reverse osmosis, filtration, adsorption, electrodialysis, chemical precipitation etc. are the different ways used for remediation of heavy metals (Mohapatra *et al.* 2007; Mohan and Gupta 2014). All these methods are not economical and eco-friendly except bioremediation. Bioremediation is the process of pollutant detoxification through the use of naturally occurring microorganisms (bacteria and fungi) (Ogden and Adams 1989). Microorganisms have a unique ability to change the compound structure that leads to complete degradation of the target molecule. Bioremediation is eco-friendly and cost effective as compared to physico-chemical methods of remediation. Bioremediation generally depends upon nature of pollutant *i.e.,* agro-chemicals, heavy metals, dyes, hydrocarbons, nuclear waste, plastics, sewage and chlorinated compounds (Lushchak *et al.* 2018).

The importance of the use of cow dung for remediation has been known recently (Bachofen *et al.* 1995). Cowdung ash is an eco-friendly and cost effective adsorbent. Calcium oxide, magnesium oxide, calcium sulphate, aluminium oxide, iron oxide and silica is present in it at concentration of 12.48%, 0.9%, 0.312%, 20%, 20% and 61%, respectively (Vasanthakumar and Bhagavanalu 2003). Utilizing cow dung as activated carbon is not only efficient and effective, but also can control other environmental issues (Qian *et al.* 2008).

Cow dung was used for the bacterial growth during arsenic volatilization as the major substrate. Detoxification of arsenic can be done by methylation process (Bachofen *et al.* 1995). Biomethylation of arsenic means the change of inorganic and organic arsenic to volatile organic dimethylarsine and trimethylarsine by methanogenic bacteria (Mohapatra *et al.* 2007).

Chromium is a hard metal that exist in mainly multivalent states. Chromium toxicity can cause respiration, liver, and kidney problems (Teklay 2016). Cowdung have quite promising adsorption capabilities of chromium ions from aqueous solution and achieved 73.8 % remediation (Mohan and Gupta 2014).

Another heavy metal named radiotoxic strontium which is highly toxic due to its long physical half-life which is found out as 29 years (Anon. 2006). Testing of Nuclear weapon testing and liquid spent reprocessing fuel like human activities are major source of its pollution. Its toxicity increases the risk of fatal diseases like blood cancer (Barot and Bagla 2012). Cowdung powder have diverse characteristics that act as site with positive charge to enzymes that result in biosorption of 90Sr from any aqueous medium (Barot and Bagla 2012).

The typical behavior of mercury in contaminated soils includes high retention, low mobility and low bioavailability. This behavior is associated with its high affinity to soil organic matter. Increased adsorption of mercury by soil components with increasing amounts of organic matter has also been reported by others (Alamgir *et al.* 2011).

Role of FYM in Pesticide Decomposition

More than 64% of the Indian population is involved in agriculture. Pesticides are used on a large scale to increase crop productivity. Nowadays, India is the 2nd largest producer of pesticides in Asia (Boricha and Fulekar 2009). Pesticides commonly have utilization efficiency of about 2–3 % and pesticide residues remain in surface soil make the environment toxic (Randhawa and Kullar 2011). At present, various physico-chemical methods being used to treat the pesticides waste; such methods are not efficient and effective.

Pseudomonas plecoglossicida is a non-fluorescent, gram-negative, rod-shaped and motile bacterium placed in the *Pseudomonas putida* group. *Pseudomonas plecoglossicida* proves to helpful for bioremediation of cypermethrin pesticide (Boricha and Fulekar 2009).

Cutworms, corn root worms, leaf folder, leaf hopper, etc. can be controlled by chlorpyrifos (Silambarasan and Abraham 2013). Chlorpyrifos is used in various

Table 4: Major herbicides and their detrimental effects

Sl. No.	Herbicides	Effects	References
1	Butachlor	Affects the various other metabolic processes and redox homeostasis adversely	Agrawal *et al.* 2014
		Stimulate cell proliferation	Xu *et al.* 2007b
2	Bispyribac	Histopathological changes in liver, lungs, kidney and spleen	Elalfy *et al.* 2017
3	Anilofos	Cause neuronal and cellular dysfunction	Hazarika and Sarkar 2001
4	Oxadiargyl	Leafy vegetable yield reduced due to its residue	Mahmoudi *et al.* 2011
5	Pendimethalin	Thyroid follicular cell adenomas in rats	Hou *et al.* 2006
		Residue results in root and shoot growth inhibition	El-Nady and Belal 2013
7	Diuron	Toxic to reproductive system of oysters and lizards	Huovinen *et al.* 2015
8	Atrazine	Liver and kidney damage in rats	Jestadi *et al.* 2014
9	Isoproturon	Decrease in soil microbial community	Widenfalk *et al.* 2004

Table 5: Insecticides and their harmful effects

Sl. No.	Insecticides	Effects	References
1	Profenophos	Somatic and germ cells chromosomal aberration which demonstrates its potential mutagenicity	Fahmy and Abdalla 1998
2	Cypermethrin	DNA damage and oxidative stress in the neuronal cells	Singh *et al.* 2012
3	Fenvalerate	Endocrine disrupting chemical	Gao *et al.* 2010
4	Spinosad	Vacuolation and inflammation of the thyroid gland also occurred in rats	Yano *et al.* 2002

formulations like granules, wet table powder, etc. (Swati and Singh 2002). Chlorpyrifos can be utilized by *Pseudomonas resinovarans* as an energy source, so it can be used for bioremediation of chlorpyrifos contaminated soils (Fulekar and Geetha 2008).

Fenvalerate is a synthetic pyrethroid used for killing pests in crop fields. Degradation of fenvalerate into 4-chloroalpha benzene acetic acid and 3-phenoxy-benzoic acidovera is done by various microbes present in soil, which is less toxic than the parent compound (Geetha and Fulekar 2010).

Atrazine is a herbicide that interferes with photosynthesis in various broad-leaf plants. Its residue is not only toxic to plants but also reaches into streams and rivers through runoff. Incubation studies showed that the degradation of atrazine was the fastest in farmyard manure treatments (Mukherjee 2009).

Pseudomonas has a great potential to degrade chlorpyrifos (Horne *et al.* 2002). Similarly, cyanobacteria also possessed a pivotal role in the degradation of malathion (Ibrahim *et al.* 2014). Chlorothalonil is an organochlorine and non-systemic fungicide (April *et al.* 2014).

The role of other microorganisms such as *Azomonas*, *Flavobacterium*, *Moraxella*, *Pseudomonas*, *Micrococcus spp*. and other gram-positive rods have been described for chlorothalonil degradation (Mori *et al.* 1996).

Effect of integrated nutrient management on soil properties, plant growth and nutrient uptake

Effect on soil properties

(a) *Effect on soil physico-chemical properties*

Bandyopadhyay *et al.* (2010) demonstrated the influence of FYM and chemical fertilizers on soil health under the soybean at Indian Institute of Soil Science, Bhopal, Madhya Pradesh. They noticed that conjunctive use of synthetic fertilizers with organic manure considerably inclined the soil organic carbon by 29.8% and 45.2% comparative to full NPK and control treatment. Shirale *et al.* (2014) reported a maximum decline in pH (-0.17) with FYM @ 10 Mg ha^{-1} and maximum EC was observed in plots that received the higher amount of inorganic fertilizers whereas the highest positive change in organic carbon (+1.10) was found under the treatment of 150% NPK.

Kaur *et al.* (2005) revealed that soil pH varied from 7.58 to 7.65 under various treatments that received various organic manures. Maximum fall in pH (7.58) was recorded in treatment comprised of FYM @ 15 t ha^{-1} + N 120 kg P 30 kg in wheat and N 120 kg P 60 kg in pearl millet. Maximum 0.99% organic carbon was recorded with the application of FYM @ 15 t ha^{-1}. Sepehya *et al.* (2012) investigated that

Table 6: Percentage increase observed in soil available N, P, K and organic carbon under integrated nutrient management over the conventional nutrient management practices (Fertilizers only) in different cropping systems

Sl. No.	Cropping system	Available Nitrogen	Available Potassium	Available Potassium	Organic Carbon	References
1	Maize–mustard crop sequence	57.9%	68.2%	39.7%	27.0%	Saha *et al.* 2010
2	Direct seeded upland rainfed rice	13.9%	40.6%	20.6%	13.6%	Choudhary and Suri 2014
3	French Basil	17.6%	12.7%	3.2%	11.4%	Anwar *et al.* 2005
4	Rice-wheat crop sequence	78.8%	40.1%	13.5%	24.2%	Ram *et al.* 2016
5	Baby corn-rice cropping system	24.6%	27.5%	9.0%	10.0%	Sharma and Banik 2016
6	Cotton	11.7%	9.4%	15.9%	17.6%	Reddy *et al.* 2017
7	Sugarcane	8.3%	20.8%	21.4%	12.2%	Bokhtiar and Sakurai 2005
8	Cauliflower	11.9%	22.3%	9.13%	22.5%	Chahal *et al.* 2019
9	Rice-wheat cropping system	15.3%	57.7%	22.9%	50.0%	Walia *et al.* 2010
10	Rice-wheat cropping system	10.2%	15.2%	8.4%	12.1%	Bahadur *et al.* 2012

the application of 50% NPK + 50% N through FYM resulted in significantly higher soil organic carbon (90.0 g kg^{-1}) and CEC [14.1 cmol (p^+) kg^{-1}].

Gopinath *et al.* (2009) revealed that long-term application of FYM increased the soil pH (6.95) over the initial status (6.90). Similarly, FYM application escalated the soil organic carbon content to 1.10% from 1.02%, which was at the initial level.

Table 7: Effect of nutrient management on soil organic carbon pool (Brar *et al.* 2015)

Treatments	Soil organic carbon pool (Mg ha^{-1})		
	1971	2007	Change
50% NPK	5.70	8.40	2.70
100% NPK	5.00	8.70	3.70
100% NP	4.20	8.10	3.90
100% N	4.20	7.70	3.50
100% NPK + FYM	4.90	11.60	6.70

Desta (2015) conducted a field trial to examine the influence of organic manures and chemical fertilizers on soil properties under maize at Antra catchment located in Chilga. He described that combined application of organic and inorganic fertilizers improved the soil pH, organic carbon and cation exchange capacity over the control.

Adeniyan *et al.* (2011) evaluated the effect of different organic manures with NPK fertilizers in a pot experiment to improve soil chemical properties. They reported that cow dung application increased the pH to 6.30 from acidic level that was 5.08 at the initial. Besides that, treatment of cane rat droppings resulted in higher organic carbon (1.96%) and CEC [3.10 cmol (p^+) kg^{-1}] than NPK alone application.

Parvathi *et al.* (2013) examined the soil nutrient status during 1981-2011 under the intensive cropping of groundnut at Regional Agricultural Research Station, Andhra Pradesh. FYM @ 5 t ha^{-1} once in 3 years resulted in highest soil pH (5.57) as well as highest organic carbon content (0.40%). Apart from this, maximum EC (0.07 dS m^{-1}) was recorded in NPK + Gypsum + $ZnSO_4$ applied treatment.

Sunitha *et al.* (2010) conducted a field trial at the Agricultural Research Station, Honnavile, Shivmoga during Kharif 2007. They found that the application of 100% N declined the soil pH. Maximum cation exchange capacity [8.99 cmol (p^+) kg^{-1}] was recorded under treatment of 50% N + 25% N through Green leaf manure + 25% N through FYM + *Azospirillium* as compared to control where CEC was 7.92 cmol (p^+) kg^{-1}. FYM along with *Azospirillium* resulted in highest organic carbon (6.90 g kg^{-1}).

Sharma *et al.* (2017) studied the effect of INM on the soil properties in onion. They showed that soil pH did not differ significantly under different treatments. Soil pH varied from 6.0 to 6.4. Maximum SOC was recorded in two treatments viz. 20 t ha^{-1} FYM + NPK (150-100-75 kg ha^{-1}) and 10 t ha^{-1} FYM + mustard oil cakes (1 t ha^{-1}) + NPK (125-100-100 kg ha^{-1}).

An investigation was carried out by Jat and Singh (2017) at Agricultural Research Farm, Banaras Hindu University, Varanasi to describe the influence of INM on the soil. Soil pH varied from 7.93 (70% RDF + 30% N by pressmud) to 8.32 (control). Significantly superior organic carbon (0.48%) and CEC [10.17 cmol (p^+) kg^{-1}] was recorded with the treatment of 70% RDF + 15% N through FYM + 15% N through pressmud.

(b) *Effect on soil biological properties*

Table 8: Percentage increase observed in microbial biomass under different crop management practices over conventional management practice (Fertilizers + Herbicides + Insecticide) (Fraser *et al.* 1988)

Soil depth	Crop management	Microbial biomass
0 to 7.5 cm	Fertilizers + Herbicides	7.3%
	Fertilizers only	17.1%
	Manures only	39.0%
7.5 to 15 cm	Fertilizers + Herbicides	3.7%
	Fertilizers only	7.5%
	Manures only	11.3%

An investigation was carried out by Bahadur *et al.* (2012) to evaluate the effect of INM on microbial population under rice-wheat cropping system. They stated that application of 100% NPK + FYM @ 5t ha^{-1} + *Azotobacter* increased the total bacteria ($79*10^5$ cfu g^{-1} soil), *azotobacter* ($45*10^5$ cfu g^{-1} soil), PSB ($35*10^2$ cfu g^{-1} soil) and actinomycetes ($18*10^5$ cfu g^{-1} soil) as compared to control in which bacteria, azotobacter, PSB and actinomycetes was $37*10^5$ cfu g^{-1}, $18*10^2$ cfu g^{-1}, $9*10^2$ cfu g^{-1} and $10*10^5$ cfu g^{-1} soil, respectively.

Kumar *et al.* (2017) conducted an experiment to study the influence of the combined application of organic manures with chemical fertilizers on soil microorganisms. They described that bacterial and fungal population was affected significantly with organic manures application. Abundance of bacteria (8.24 log cfu g^{-1} soil) and fungi (3.89 log cfu g^{-1} soil) was found in which an integrated application of nutrient sources was done.

Kour *et al.* (2019) explained the status of the microbial population as influenced by integrated nutrient management in aonla planting. Bacterial counts varied from $11*10^5$ cfu (100% N through fertilizers) to 13.3(100% N through FYM) whereas fungal count varied from $9.7*10^5$ cfu (100 % N through fertilizers) to $24.9*10^5$ cfu (100% N through FYM).

Kuttimani *et al.* (2017) described that the fungal, bacterial, and actinomycetes population in different stages was significantly affected by integrated nutrient management under the irrigated banana. In data that was recorded at 3 and 5 months after planting, they found that the microbial population was increased with the advancement of banana crop growth. Application of 100% recommended dose of fertilizers (RDF) + FYM resulted in better bacterial ($37.01*10^5$ g^{-1}), fungal ($20.86*10^3$ g^{-1}) and actinomycetes ($24.82*10^2$ g^{-1}) population over control.

Gudadhe *et al.* (2015) evaluated the response of INM on soil properties under cotton-chickpea cropping sequence at Mahatma Phule Krishi Vidyapeeth, Rahuri. They demonstrated that the maximum viable count of bacteria, fungi, and actinomycetes ranged from (20.20 to 36.30)$*10^3$, (15.30 to 33.50)$*10^{3,}$ and (36.70 to 58.30)$*10^3$ cfu g^{-1} soil, respectively. Maximum abundance of microbes in soil was found in treatment comprised of 10t FYM + RDF.

Khan *et al.* (2017) conducted a field trial at the Mountain research centre for field crops Khudwani to investigate the influence of nutrient management on the biological properties of soil. , The microbial population, was increased significantly in plots where organic manures were applied. Treatment consisted of 75% NPK + 25% N through FYM possessed highest bacterial ($68.66*10^5$ cfu g^{-1} soil), fungal ($71.33*10^5$ cfu g^{-1} soil) and actinomycete ($57.33*10^5$ cfu g^{-1} soil) counts over all other treatments.

Meena *et al.* (2019) revealed the influence of INM on soil properties under sapota (*Achras zapota* L.) They revealed that maximum improvement in microbial population *i.e.,* fungi (8.63 cfu g^{-1} soil in 2013 and 9.16 cfu g^{-1} soil in 2014) and bacteria (8.89 cfu g^{-1} soil in 2013 and 13.48 cfu g^{-1} soil in 2014) was recorded in treatment comprised of two third part of recommended NPK + 10 kg vermicompost + 250g *azospirillium* + 250g *azotobacter* $plant^{-1}$ which was at par with treatment in which ½ RDF + 250g *azospirillium* + 250g *azotobacter* $plant^{-1}$.

Vineela *et al.* (2008) demonstrated the effect of cropping and nutrient management practices on microbial properties of soil in long term experiment. They stated that 85.2% more bacterial population was found in treatment comprised of NPK application on soil test basis through fertilizers along with FYM @ 5t ha^{-1} over the control whereas in same treatment fungal and actinomycetes population was found 6.9% and 13.9%, respectively more over the control.

Effect on plant growth

Ahmad *et al.* (2014) studied the influence of combined application of farmyard manure, leaf manure, poultry manure, and chemical fertilizers on the growth and yield of carrot. Plant height (39.98 cm) and root length (21cm) were recorded maximum when total nitrogen requirement was completed through poultry manure and farmyard manure as compared to control in which plant height and root length were recorded 22.42 cm and 11.25 cm, respectively.

Shree *et al.* (2014) examined the response of cauliflower to dose of various organic manures and synthetic fertilizers. Maximum yield was obtained (252.48 q ha^{-1}) through the application of ½ NPK + FYM @ 5 t ha^{-1} + vermicompost @ 2 t ha^{-1} + *Azospirillum* as compared to yield (235.71 q ha^{-1}) in RDF treated plots.

Prabhakar *et al.* (2015) demonstrated the effectiveness of various organic sources of nutrients on cauliflower. Maximum curd yield (21.23 t ha^{-1}) was recorded with the combined use of organic and chemical fertilizers. An experiment was laid down by Manohar *et al.* (2013) and described that maximum yield (359.24 q ha^{-1}) yield was obtained with the dose of FYM @ 20 t ha^{-1}. Likewise, the highest plant height (60.98 cm) and no. of primary branches/plant (6.79) was also recorded with 20 t ha^{-1} FYM application.

Malik *et al.* (2011) studied the influence of combined use of inorganic fertilizers and organic manures on sweet pepper (*Capsicum annuum* L.). They reported that the combined use of inorganic fertilizers along with FYM @ 40 t ha^{-1} resulted in a maximum number of fruits per plant (20.45 and 19.00), fruit length (8.40 and 8.20 cm), fruit diameter (8.09 cm and 7.70 cm), average fruit weight (94.85 g and 93 g) and average fruit yield/plot (38.79 kg and 35.34 kg).

A research was undertaken by Chaudhary *et al.* (2018) to investigate the effect of INM on yield and growth of cabbage. They revealed that the highest head length (17.5 cm) and head diameter (14.7 cm) was obtained with the application of 100% RDF. However, maximum head weight (1176.7 g) and yield (470.7 q ha^{-1}) was recorded in 50% N as mineral fertilizers + 50% N through FYM treated plots.

Mohanta *et al.* (2018) studied the influence of INM on broccoli and revealed that the application of 50% NPK fertilizers + FYM @ 10 t ha^{-1} inclined the plant height (54.68 cm) and head diameter (13.83 cm). Maximum gross yield (233.56 q ha^{-1}) was observed under treatment comprised of 50% NPK + vermicompost @ 2.5 t ha^{-1}.

Prativa and Bhattarai (2011) described that highest plant height (116.16 cm), individual fruit weight (52.80 g), and yield (25.74 Mt ha^{-1}) were recorded under application of 16.66 Mt ha^{-1} FYM + 8.33 Mt ha^{-1} vermicompost + NPK. Kumar (2016) revealed that maximum plant height (166.30 cm), dry weight (102.36 g) and yield/plant (6084.25 g) was obtained when 50% RDF was applied along with vermicompost @ 5 t ha^{-1}.

Kumar and Biradar (2017) conducted an experiment at Main Agriculture Research Station, University of Agricultural Sciences, Dharwad to demonstrate the influence of integrated nutrient management on the yield of broccoli. Maximum plant height (35.4 cm), plant spread (83.4 cm^2), stalk length (23.4 cm), curd weight (398 g), curd diameter (18.0 cm) and curd yield (19.5 t ha^{-1}) was obtained with the use of 75% RDF + FYM + Vermicompost (1:1) equivalent to 25% RDN.

Effect on nutrient uptake

Chandel *et al.* (2017) assessed the response of cotton and green gram in intercropping to INM at Research field of AICRP for Dryland Agriculture, Maharashtra. They stated that maximum available N (257.2 kg ha^{-1}), available P (15.8 kg ha^{-1}) and available K (362.1 kg ha^{-1}) was recorded under treatment of 50% N through inorganic fertilizers + 50% N through FYM + 100% P_2O_5 fertilizer. Likewise, Deshmukh *et al.* (2005) also observed the highest uptake of N, P and K as well as available N, available P, and K with the combined use of FYM with recommended fertilizers.

A field experiment was conducted by Devi *et al.* (2018) to study the impact of integrated nutrient management on soil nutrient status along with the growth and yield of cauliflower. They revealed that the application of 130% NPK (50:50 of FYM and VC as per N content) significantly increased the available N (406.55 kg ha^{-1}), P (69.20 kg ha^{-1}), K (309.35 kg ha^{-1}) and S (59.20 kg ha^{-1}). Devi *et al.* (2017) also evaluated the biological properties and nutrient uptake in cauliflower through integrated nutrient management. They stated that higher values of N (64.57 kg ha^{-1}), P (9.91 kg ha^{-1}) and K (50.77 kg ha^{-1}) uptake were obtained under the treatment comprised of 130% NPK (50:50 of FYM and VC as per N content).

The effect of integrated nutrient management on soil fertility under rice-wheat system was studied by Kumari *et al.* (2017). They opined that maximum organic carbon content (0.77%), available N (225.95 kg ha^{-1}), available P (49.54 kg ha^{-1}) and sulphur (14.41 kg ha^{-1}) was obtained with the application of 50% RDF + 50% N through FYM. Nitrogen uptake varied significantly from 11.54 to 70.98 kg ha^{-1} under the FYM applied treatments, whereas maximum variation (17.86 to 104.45 kg ha^{-1}) occur in straw incorporated treatments.

Effect of integrated nutrient management on rice was evaluated by Priyanka *et al.* (2013) at the Research Farm of CSKHPKV, Palampur, Himachal Pradesh. The experiment was laid down with 3 different FYM levels (0, 10 and 20 t ha^{-1}) and 3 fertilizers levels (0, 50 and 100% RDF). They opined that maximum level of FYM application (20 t ha^{-1}) resulted in highest N content in rice grain as well as K in its straw whereas P content was remained unaffected, this might be due to reason that phosphorus is slowly released from the FYM.

Phullan *et al.* (2017) also assessed the influence of FYM under the wheat crop and found that FYM application increased the N uptake by 14% whereas in case of full dose of inorganic fertilizers N uptake was 81% higher over the control. P and K uptake was quite high *i.e.*, 66% and 56%, respectively in plots treated with inorganic fertilizers as compared to control.

CONCLUSION

From the above review, it is clear that farmyard manure addition into soil enhances soil health and plant growth. The application of organic amendments increases the organic carbon stock in the soil. Soil organic matter incorporation through FYM results in the formation of organic colloids that means a large number of sites are available for nutrient exchange. Organic matter also promotes the chelation of soil nutrients. Farmyard manure use in fields is also a cost-effective way for bioremediation of heavy metals, pesticides, and herbicides. In a present age, where chemical fertilizers are dominantly ruling in agriculture and possessing a great threat to ecological balance, the advantage of organic manure use needs to understand. Therefore, farmers must be made aware of the benefits of farmyard manure cost-effectiveness and efficiency.

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