

Review Article

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Performance of Rice under Integrated Nutrient Management: A Review

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ABSTRACT

Excessive application of chemical fertilizers to attain higher yield has not only reduced the nutrient use efficiency but has also adversely affected the soil productivity and environmental stability. For this reason, immediate conversion to organic farming would drastically reduce production at initial phases which is of major concern to feed the growing population. This article is written with prime focus to notify on the yield variability under different integrated nutrient management approaches from research conducted worldwide. Organic manures like farmyard manure (FYM), green leaf manure (GLM), vermicompost (VC) and poultry manure (PM) are prioritized due to local availability with integration with inorganic fertilizers on growth and yield of rice. From the study, integrated nutrient management is the best practice over chemical fertilizers and also over complete shift to organic cultivation in terms of improving productivity and also maintaining soil health but over a long run. Selection of organic manures can be made from local availability to decrease the cost of cultivation over inorganic fertilizers as well as other organic sources of fertilizers.

Keywords

Integrated nutrient management,
Farmyard manure,
Green leaf manure,
Vermicompost,
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Introduction

Rice (*Oryza sativa* L.) is one of the principal food crops in India and it is grown in diverse agro-ecosystems. After the green revolution, due to the introduction of high yielding and fertilizer responsive varieties, rice cultivation has been intensified and has led to increase the use of chemical fertilizers and pesticides. This increased use of chemicals led to several

harmful effects on soil, water and atmosphere causing pollution and reduced productivity of the soil (Surekha *et al.*, 2008).

To sustain the soil health and to provide adequate plant nutrition, an alternative to chemical fertilizers need to be supplied in integration as sudden stoppage of chemical and total conversion to organic would lead to drastic yield gaps during the early stages

(Singh *et al.*, 2009a). The demand for rice is expected to rise @ 1.6 per cent per year due to increase in population, while the area under rice cultivation is expected to reduce to 40 million ha in the next 15 to 20 years (Shobarani *et al.*, 2010). Hence, there is a need to increase the yield and productivity of rice cultivation using reduced inputs and resources to feed the burgeoning population. Moreover, increased cost of chemical fertilizers is reducing the profitability of cultivation. Therefore, alternative use of organic manures like green manuring and crop residues along with inorganic fertilizers not only reduces the demand of inorganic fertilizers, but also increases the efficiency of applied nutrients due to favourable effect on physical, chemical and biological properties of soil (Prasad *et al.*, 1992).

The effectiveness of integrated nutrient management practice can depend on season, soil type, climate, water management, variety and cropping pattern. Thus, this article is written to discuss on the nutrient management strategy involving alternate nutrient management at timing and rates, and integration of organic and other inorganic sources of fertilizers.

Effect of inorganic fertilizer on soil fertility

Several long-term experiments conducted all over India indicated that a decrease in rice productivity was noticed due to continuous use of chemical fertilizers (Prasad *et al.*, 1995). Basumatary and Talukdar (1998) indicated that continuous application of chemical fertilizer alone decreased the pH, organic carbon, cation exchange capacity and available N content of soil, whereas an improvement over initial value resulted under integrated treatments receiving both inorganic and organic sources of fertilizer. Yadav (2000) opined that under a continuous cropping, the decline in yield may either be

reversed or minimized by application of complete doses of fertilizer NPK.

Singh *et al.*, (2009a) observed that available phosphorus and potassium were higher in inorganic plots as compared to organic and integrated plots. Application of inorganic NPK alone registered lower NPK uptake at harvest than integrated nutrient management practices (Senthivelu and Prabha, 2007). Chandrakumar *et al.*, (2008) found that continuous application of inorganic fertilizers affected the microbial population and leads to clod formation and reduced the fertility status of the soil by affecting the multiplication of microbial population in soil.

Effect of organic manure on soil health

Organic manures addition in the soil plant ecosystem is an essential component of sustainability in nutrient exhaustive rice cropping system. It influences the microbial activity in the soil and subsequent nutrient transformation (Kumar and Goh, 2000). Farmyard manure is being used as major source of organic manure in field crops and its role in crop production cannot be overlooked. In addition to supplying all essential nutrients, it increases the activities of bacteria or microbes in soil (Sutaliya and Singh, 2005).

Organic manures are reported to enhance the fertilizers use efficiency and reduce the requirement of inorganic fertilizers. Use of organic manure significantly increased the availability of the limiting nutrients in the soil and maintains the soil fertility in rice (Vats *et al.*, 2001). Swarnkar *et al.*, (2005) observed that use of green manure, especially *Sesbaniarostrata*, which nodulates in roots as well as in stems, performed better and maintained the nutrient supply in rice cultivation.

Ibeawuchi *et al.*, (2006) observed in a degraded soil of Nigeria that poultry manure application increased the residual soil N, K, Ca, Mg and organic matter. Biswas *et al.*, (2007) reported that microbial biomass, carbon and soil organic carbon were responded positively to application of organics (Farmyard manure, *Leucaena leucocephala* and rice residues) in conjunction with inorganics and also sustained release of nitrogen to the crops in rice-wheat system.

Organic manures improved the soil fertility status and it was pronounced by the dhainchain corporation by increasing organic carbon content (0.7%), available soil N (209.6 kg ha⁻¹), P (18.6 kg ha⁻¹) and K (249.0 kg ha⁻¹) at post-harvest stage (Hemalatha *et al.*, 2000).

Application of organic manures favoured the microbial population, which in turn helped to release bounded or unavailable form of nutrients to available form (Chandrakumar *et al.*, 2008). Highest organic carbon (0.84 %) was also reported in rice by Singh *et al.*, (2009a), when managed organically. Organic carbon and infiltration rate were high with the application of organic manures through press mud, green manure (*dhaincha*) and green leaf manure under continuous submergence of sodic soil (Singh *et al.*, 2009b).

Sharma *et al.*, (2008) reported that uptake of N, P, K and Zn (85.7, 17.9, 100.8 and 0.60 kg ha⁻¹ respectively) was maximum under vermicompost application at 3 t ha⁻¹ in rice. Babou *et al.*, (2009) recorded that soils amended with organic manures (FYM at 12.5 t ha⁻¹ + Panchagavya at 3% + Amuthakaraisal at 1%) consistently registered improved organic carbon, mineral, total N and grain yield (11257 µg g⁻¹, 26.33 µg g⁻¹, 1157 µg g⁻¹ and 7.2 t ha⁻¹ respectively) compared to un-amended soil (7215 µg g⁻¹, 9.21 µg g⁻¹, 481

µg g⁻¹ and 2.7 t ha⁻¹ respectively). Under different organic sources, the total and individual population of different microorganisms was higher in wheat straw amendment and was followed by green manure and FYM application in the long-term experiment (Bedi *et al.*, 2009).

Surekha and Rao (2009) opined that addition of nutrients through organic manures and the release of these nutrients from the organics depend on their C:N ratio and lignin content. The application of enriched poultry manure compost and composted poultry manure recorded maximum soil available N, P and K as compared to application of recommended NPK fertilizer was reported by Sangeetha *et al.*, (2010).

Sharma and Sharma (2004) found that NPK + FYM showed the highest increase in organic C, available N, available P and available K content in soil compared to other inorganic treatments. Datta and Singh (2010) revealed that organic carbon increased from 6.5 to 8.3 g kg⁻¹ due to application of cattle manure at 10 t ha⁻¹ in rice – greengram cropping system.

Effect of INM practices on rice

The concept of integrated nutrient management (INM) seems to sustain the soil fertility through integration of different nutrient sources and their application to produce maximum crop yield per unit input used. Several studies indicated that application of fertilizer N in conjunction with organic sources is known to stimulate the mineralization and then immobilization of organic N and reduced the losses of nitrogen.

Integrated nutrient supply is important as a soil ameliorant in alleviating the adverse soil ecological conditions and in improving soil fertility and productivity (Singh *et al.*, 2009a).

Effect of INM on soil health

Integrated nutrient management in which both organic manures and inorganic fertilizers are used simultaneously has been suggested as the most effective method to maintain a healthy and sustainable soil system, while increasing crop productivity (Satyanarayana *et al.*, 2002).

Kumar *et al.*, (1999) observed that yield and soil fertility were improved, when organic materials such as green manure at 1.5 t ha⁻¹, groundnut haulm at 3.0 t ha⁻¹ and mustard stover at 5.0 t ha⁻¹ were combined with inorganic fertilizers to supply the recommended amounts of nutrients, while inorganic fertilizers alone did not increase the organic carbon content of the soil.

Integrated nutrient management practices showed significantly higher grain yield (5.77–7.56 t ha⁻¹) than chemical fertilization alone (4.32 t ha⁻¹), because of presence of humic acid compounds in soil, which helped in dissolution of minerals and chelation of micronutrients (Raju and Sreenivas, 2008).

Soil analysis for microbial population count at rice harvest stage showed an increase in microbial (actinomycetes, bacteria and fungi) population and soil enzymatic activity under Integrated Plant Nutrient Supply (IPNS) compared to sole chemical fertilizer application (Singh *et al.*, 2006).

Bedi *et al.*, (2009) observed that total microbial population was minimum in the absolute control and maximum, where 50 per cent nitrogen was substituted by wheat straw in the long-term experiment. Integrated nutrient supply is important as a soil ameliorant in alleviating the adverse soil ecological conditions and in improving soil fertility and productivity (Singh *et al.*, 2009a).

Effect of integrating farmyard manure (FYM) on rice

In a comparative study, Singh *et al.*, (2001) noticed that grain (3.6 t ha⁻¹) and straw (4.2 t ha⁻¹) yields of rice increased due to combined application of 50 per cent recommended NPK + FYM in both shallow and semi-deep water situations over 100 per cent RDF (1.77 t ha⁻¹). Further, they reported that higher yield in the NPK+FYM treatment was due to the prolonged availability of plant nutrients. Satheesh and Balasubramanian (2003) inferred that application of FYM at 10 t ha⁻¹ in combination with neem cake at 3.0 t ha⁻¹ found to be equally effective for getting higher grain yield (5.6 t ha⁻¹) and improved nutrient uptake (163.9, 52.4, 133.4 kg NPK ha⁻¹), when compared to application of chemical N fertilizers alone.

Rao *et al.*, (2004) stated that 50 per cent N through fertilizer and 50 per cent N through different organics would have facilitated better photosynthesis activity and promoted the dry matter production. The growth parameters increased significantly by the combined use of fertilizer nitrogen and FYM *i.e.* 75 per cent recommended dose of nitrogen through urea and 25 per cent recommended dose of nitrogen through FYM (Anny *et al.*, 2005).

Dinesh *et al.*, (2006) reported that highest grain yield with 50 per cent compost + 50 per cent NPK source, which was at par with 50 per cent FYM + 50 per cent NPK and both the practices produced significantly higher grain yield over FYM or compost or NPK fertilizer alone. Rice grain yield was significantly higher with the crop receiving 50 per cent N through chemical fertilizer and 50 per cent N through FYM followed by the crop receiving 75 per cent N through chemical fertilizer and 25 per cent N through FYM (Subhendu and Adhikary, 2005).

Senthivelu and Prabha (2007) observed that FYM application @ 12.5 t ha⁻¹ in combination with the scheduled fertilizer dose of 150:50:50 kg ha⁻¹ registered significantly the higher dry matter production (10902 kg ha⁻¹), grain yield (5538 kg ha⁻¹) and straw yield (8693 kg ha⁻¹).

Mankotia *et al.*, (2008) reported that application of FYM at 5 t ha⁻¹ with 100 per cent RDF (90 kg N, 17.4 kg P₂O₅ and 33.3 kg K₂O ha⁻¹) produced higher grain yield (5.03 t ha⁻¹) than chemical fertilizers (4.8t ha⁻¹) alone. In rice, treatment receiving FYM at 12.5 t ha⁻¹+ 150: 50: 50 kg ha⁻¹of NPK recorded higher grain yield (5.5 t ha⁻¹) and straw yield (8.7 t ha⁻¹) than inorganic fertilizers alone (Senthivelu *et al.*, 2009).

Rathi *et al.*, (2008) revealed that the highest grain yield (4.3 t ha⁻¹) and straw yield (5.1 t ha⁻¹) and NPK uptake (74.6, 21.5, 85.6 kg ha⁻¹) were obtained with 100 per cent recommended dose of inorganic fertilizers in combination with FYM 10 t ha⁻¹.The increased grain yield was mainly due to increased number of tillers hill⁻¹, filled grains panicle⁻¹ and 1000 grain weight. Highest number of tillers m⁻² were recorded when the crop was fertilized with 50 per cent RDF + FYM @ 5 tonnes ha⁻¹+ *Azotobacter* + neem cake @ 2.5 tonnes ha⁻¹+PSB @ 5 kgha⁻¹ (Ghulam *et al.*, 2009).

Highest rice productivity (7.1 t ha⁻¹) was obtained with the application of 75 per cent N supplied through inorganic source and 25 per cent through FYM (Kharub and Chander, 2010).Kumar *et al.*, (2010) observed that the yield attributes *viz.*, number of effective tillers hill⁻¹, panicle length, test weight and grain yield (5.7 t ha⁻¹) of rice was higher under 100 per cent recommended dose of NPK fertilizer in combination with FYM at 20 t ha⁻¹+ blue green algae at 10 kg ha⁻¹.

Gogoi *et al.*, (2010) observed that application of 50 per cent N through farmyard manure along with 50 per cent of recommended dose of fertilizers (60: 20: 40 NPK kg ha⁻¹) increased the yield attributes such as effective tiller number, panicle length, filled grains panicle⁻¹, test weight of seed, grain (4.1 t ha⁻¹) and straw (7.1 t ha⁻¹) yields.

Chandrapala *et al.*, (2010) observed that application of 300:17.6:33.3 kg N: P₂O₅:K₂O ha⁻¹ and 5t ha⁻¹ FYM to rice crop recorded the highest quantity of available soil N, P and K (219:31:246 kg ha⁻¹).

Shah and Sandeep (2014) reported that substitution of 50 per cent of NPK through 10 to 15 tonnes of FYM or integrated use of FYM 5 t ha⁻¹+ PSB @ 5 kg ha⁻¹ + *Azotobacter* + neemcake @ 2.5 t ha in hybrid rice crop resulted into higher productivity of hybrid rice over application of 100 per cent NPK through chemical fertilizers.

Effect of FYM soil fertility and nutrient uptake

The highest values of N uptake (49.0 kg ha⁻¹) were observed in rice with application of NPK (80: 50: 50 kg ha⁻¹) + FYM at 10 t ha⁻¹ (Sengar *et al.*, 2000). Sharma and Sharma (2004) recorded the increase in organic carbon and available N, P and K contents in soil due to combined application to FYM and inorganic fertilizers.

Application of NPK fertilizer in combination with FYM registered the higher uptake of N, P and K by both grain and straw (Natarajan *et al.*, 2005).The maximum nutrient uptake (154.2, 24.8 and 171.6 kg NPK ha⁻¹) at harvest stage was noticed with FYM at 12.5 t ha⁻¹ with RDF than inorganic fertilizers alone (Senthivelu *et al.*, 2009). Application of 100 kg of N along with FYM at 10 t ha⁻¹ recorded

the highest uptake of 135.5, 29.47 and 144.53 kg ha⁻¹ of NPK in rice (Goud and Konde, 2009). Kalaiyarasi (2009) found that application of FYM and biofertilizers along with the recommended chemical fertilizer enhanced the microbial consortia, improved the root biomass and root colour from black to brown and brown to white.

Chandrapala *et al.*, (2010) observed that application of NPK at 300:17.6:33.3 kg ha⁻¹ and 5 t ha⁻¹ FYM to rice crop recorded the highest quantity of available soil N, P and K (219:31:246 kg ha⁻¹) after crop harvest and this might be due to the slow release of nutrients from FYM and also due to chelating effect of FYM.

Bhowmick *et al.*, (2011) found that higher yields under combined use of RDF and FYM could be attributed to well decomposition of FYM, which favoured better nutrient availability coupled with higher assimilation of nutrients. Organic carbon content of surface soil increased significantly with integrated use of FYM and Zn fertilizers over control (Vipin *et al.*, 2011).

Nayak *et al.*, (2012) found that the application of inorganic fertilizer along with FYM significantly increased the available NPK and micronutrient content of soil, which was followed by application of inorganic fertilizer alone resulted with increase in NPK but slight decline in micronutrient contents *viz.*, Zn, Fe, Cu and Mn. Thus, application of inorganic fertilizer along with FYM is an effective way of sustaining soil properties in subtropical paddy soils.

Relatively more nitrogen, phosphorus and potassium uptake by hybrid rice crop was recorded from the plot in which NPK 50 per cent RDF+ neem cake @ 2.5 t ha⁻¹ + FYM @ 5 t ha⁻¹ + *Azotobacter*+ PSB @ 5 kg ha⁻¹ was applied as reported by Shah and Sandeep

(2014). Higher N, P and K uptake by grain and straw (56.0 and 26.7 kg ha⁻¹ respectively) was observed with the application of FYM @ 10 t ha⁻¹ + 100 percent RDF but was comparable with the treatment of 100 percent of RDF alone (Ranjitha and Reddy, 2014).

Effect of integrating green leaf manure (GLM) on rice

Green leaf manuring was better than FYM and this difference was reflected in all the growth and yield attributes, and consequently yield increase with GLM over FYM was 9.9 to 10.1 per cent. Presumably, the faster decomposition of GLM by soil microbes release more CO₂, speeds up chemical reaction and improve the nutrient availability (Jeyajothi and Nalliah Durairaj, 2015).

Chapale and Badole (1999) reported that significantly higher grain (52.08 q ha⁻¹) and straw (83.28 q ha⁻¹) yields were recorded under *Glyricidia* foliage @ 5t ha⁻¹ over the control. Raju and Reddy (2001) reported that incorporation of *Glyricidia* lopping (5 t ha⁻¹) with recommended dose of NPK resulted in 15.4 per cent yield increase and recorded higher B:C ratio (2.10) as compared to application of 100:50:50 kg NPK ha⁻¹ (1.40).

Gill *et al.*, (2008) stated that integrated nutrient management with green manuring as a substitute saved 50 per cent of the chemical fertiliser, with an average productivity of rice (4.8 t ha⁻¹) and wheat (3.3 t ha⁻¹) in rice-wheat system. Urkurkar *et al.*, (2010) reported that among the different sources of nitrogen substitution, the highest yield of rice (6.3 t ha⁻¹) were obtained with the 50 per cent of N substituted through green manures.

Application of 50 per cent recommended dose of fertilizers (100 kg N: 50 kg P₂O₅: 50 kg K₂O ha⁻¹) along with 50 per cent N substitution through *Glyricidia* to rice

recorded higher grain yield (7.2 t ha^{-1}) than inorganic fertilizers (6.8 t ha^{-1}) alone (Talathi *et al.*, 2009b). Rao *et al.*, (2004) observed that the highest grain yield (5.9 t ha^{-1}) was recorded with the combination of 50 per cent N each through fertilizers and *Glyricidia* leaf manure in rice.

Yadav *et al.*, (2007) revealed that application of 100 per cent RDF of $80:50:50 \text{ N:P}_2\text{O}_5:\text{K}_2\text{O}$ kg ha^{-1} along with *Glyricidia* at 10 t ha^{-1} in rice recorded the highest panicle weight (3.5 g), grain yield (3.4 t ha^{-1}), straw yield (3.9 t ha^{-1}) and biological yield (7.3 t ha^{-1}). Kamble *et al.*, (2008) revealed that incorporation of *Glyricidia* and poultry manure at 5 t ha^{-1} produced higher grain yield (5.2 t ha^{-1}) than *Glyricidia* and poultry manure at 2.5 t ha^{-1} and control in rice.

Effect of GLM on soil health and nutrient uptake of rice

Halepyati and Sheelavantar (1993) reported that N substitution with green leaf manure in rice production gave significantly higher N uptake. The organic carbon status of soil (1.33%) enhanced by application of 50 per cent N through chemical fertilizers along with 50 per cent N through *Sesbania rostrata* than initial level (0.71%) was reported by Raju and Reddy(2000).

Kaleeswari *et al.*, (2012) stated that green leaf manuring increased the N, P and K uptake by grain. Saravanapandian (2009) opined that the combined application of manures and fertilizer also significantly influenced the uptake of S by the rice crop. The highest S uptake was registered with the application of GLM with N, P and K fertilizer.

Talathi *et al.*, (2009a) reported that the N, P and K uptake was higher with application of *glyricidia* (99.6, 27.6 and 82.6 kg ha^{-1} respectively) in conjunction with chemical

fertilizers compared to control in hybrid rice. Sunitha *et al.*, (2010) found that application of 50 per cent N through urea + 25 per cent N through green leaf manure (*Glyricidia maculata*) + 25 per cent N through FYM + Azospirillum recorded the highest availability, concentration and uptake of nutrients at all the stages of rice growth over other treatments during *kharif* in sandy loam soil.

Effect of integrating vermicompost (VC) on rice

Jeyabal and Kuppuswamy (2001) opined from a rice-legume study that the integrated application of 50 per cent N through vermicompost, 50 per cent through fertilizers N and biofertilizers recorded 12.2 and 19.9 per cent higher grain yield in rice and legume (6.25 and 0.50 t ha^{-1} , respectively) than those obtained with 100 per cent fertilizers N alone.

The yield increase was 10.8 per cent with judicious use of vermicompost and inorganic fertilizer enabled rice plant to assimilate sufficient photosynthates resulting in increased drymatter production and these together produced more productive tillers, panicle and number of filled grains leading to higher grain yield (Mondal *et al.*, 2003).

Application of vermicompost favourably influenced the growth of rice (Meena, 2003; Anitha and Prema, 2003) and improved the yield components and yield in rice (Sudhakar *et al.*, 2002). Norman *et al.*, (2005) reported that vermicompost application improved plant growth of rice.

The combined application of fertilizer N, vermicompost and azolla sustained the productivity even at lower rate of N fertilizer application (Singh *et al.*, 2005). Barik *et al.*, (2006) reported that application of 50 per cent RDN in combination with vermicompost at

10 t ha⁻¹ significantly improved the growth and yield attributes of rice compared with the application of 100 per cent RDN and of different combinations of FYM and mineral fertilizers. The highest grain and straw yields were recorded when crop was supplied with 50 per cent RDN along with 10 t vermicompost ha⁻¹. Maximum grain and straw yield recorded with the application of 50 per cent RDN through urea + 50 per cent RDN through vermicompost and was found to be significantly superior over the rest of the treatments, which was followed by the treatment received 100 per cent RDN through urea (Viraktamath, 2006).

Application of vermicompost at 3.0 t ha⁻¹ produced taller plants, leaf area index and dry weight hill⁻¹ than FYM at 10 t ha⁻¹ in rice. These better growth attributes in rice under vermicompost was due to increased availability of plant nutrients as reported by Sharma *et al.*, (2008). Singh *et al.*, (2009a) reported that 25 to 50 per cent NPK can be substituted by FYM, vermicompost or FYM along with vermicompost in rice. Yield reduction of rice by substitution of 25 per cent NPK through FYM, vermicompost, press mud and 50 per cent by FYM + vermicompost over 100 per cent NPK were 2.5, 1.5, 6.3 and 7.3 per cent respectively.

Paramesh *et al.*, (2014) reported that 50 per cent RDN through chemical fertilizers + 50 per cent RDN through vermicompost recorded significantly higher plant height, leaf area, number of tillers hill⁻¹, total dry matter accumulation hill⁻¹, grain yield (39.48 q ha⁻¹) and straw yield (52.9 q ha⁻¹).

Ramalakshmi *et al.*, (2012) found that 125 per cent RDF + 5 t ha⁻¹ vermicompost increased the number of panicles, panicle length, panicle weight, 1000 grain weight, grain yield, straw yield and protein content. Kandeshwari *et al.*, (2012) revealed that

integrated nutrient management practices involving vermicompost recorded the highest grain yield (5.8 t ha⁻¹) than 100 per cent inorganic fertilizers (5.17 t ha⁻¹). Jagadeeshwar *et al.*, (2012) reported that the application of vermicompost could not only help realise higher grain yield but also to minimize problem due to biotic stresses under organic rice cultivation.

Effect of VC on soil fertility and nutrient uptake

Kale *et al.*, (1987) observed an increase in the rates of nutrients uptake with the increase in symbiotic microbial association in cereal and ornamental plants on using vermicompost as a source of organic manure. Kale and Bano (1988) opined that nutrient uptake of rice was enhanced with 50 per cent of RDF and 2.5 t ha⁻¹ of vermicompost application than 100 per cent RDF, apart from increasing grain and straw yields of upland paddy.

Kale *et al.*, (1992) observed that there was an increase in all the groups of microbes, except actinomycetes due to the application of vermicompost in place of FYM and other chemical fertilizers. They further noticed that total N content in vermicompost and FYM plots was almost same. Albanel *et al.*, (1998) reported that earthworms accelerated the mineralization rate and converted the wastes into casting with higher nutritional value.

From a rice-legume study, Jeyabal and Kuppaswamy (2001) found that vermicompost when applied in combination with chemical fertilizers increased the N, P and K uptake by 15.3, 10.7 and 9.4 per cent respectively in rice over N fertilizer alone.

Lal *et al.*, (2003) stated that vermicompost contain major and minor plant nutrients in available form that in turn improved the uptake of nutrients by the plants.

The application of vermicompost enhanced the availability of nutrients in the soil and uptake by the plants (Ushakumari *et al.*, 2006).

Sharma *et al.*, (2008) reported that uptake of N, P and K and Zn (85.7, 17.9, 100.8 and 0.60 kg ha⁻¹ respectively) was maximum under vermicompost application at 3 t ha⁻¹ in rice. Arun *et al.*, (2014) found that 125 per cent RDF + 5 t ha⁻¹ vermicompost increased P and K uptake in grain and straw over control. Application of organic manures alone and integrated nutrient management increased the available N, P and K content of soil as compared to recommended dose of fertilizer treated plots (Venkatakrishnan and Ravichandran, 2012).

Effect of integrating poultry manure (PM) on rice

Nasimul Gani (2014) stated that mixing poultry litter with chemical fertilizer enhances the yield of crop and soil fertility and also minimizes the cost of fertilizer. Amujoyegbe and Alofe (2003) reported that the integrated use of poultry manure and inorganic fertilizer increased yield and quality of cowpea by increasing crude protein content, percentage of crude fibre, total nitrogen and carbohydrate contents.

Adeniyani and Ojeniyi (2003) studied the comparative efficiency of residual effects of poultry manure and concluded that poultry manure with inorganic fertilizer gave residual effects on soil chemical composition and increased plant height, leaf area, dry matter yield, nutrient uptake and grain yield of maize significantly compared to the application of inorganic fertilizer alone. Application of 50 per cent N through composted poultry manure and 50 per cent N through green leaf manure recorded significantly higher yield characteristics of rice, when compared to

recommended dose of NPK through fertilizers (Yadav *et al.*, 2006).

Mukharjee *et al.*, (2006) conducted an experiment and revealed that maximum seed yield of rice bean (1.51 t/ha) was recorded, when the crop received 50 per cent recommended dose of nutrients applied through chemical fertilizer along with another 50 per cent recommended dose of nutrients through poultry manure. Setty *et al.*, (2007) observed that application of 50 per cent recommended dose of 100: 50:50 kg N: P₂O₅: K₂O kg ha⁻¹ through poultry manure recorded higher plant height (76.3 cm), total number of tillers (46.0), LAI (4.7), total dry matter (165.3 g hill⁻¹), effective tillers hill⁻¹ (35.9), filled grains panicle⁻¹ (271.9), lower percentage of chaffiness (7.4%) and higher grain and straw yield (8.3 and 8.6 t ha⁻¹).

Rathiya *et al.*, (2007) established a field experiment to study the effect of different organic amendments (farmyard manure, poultry manure and bio fertilizer) combined with different chemical fertilizer rates on the growth and yield parameters of sunflower. Behera *et al.*, (2007) conducted a study and concluded that grain yield of wheat was significantly increased with 50 per cent NPK+ poultry manure at 2.5 t/ha compared to other INM treatments.

Effect of PM on soil fertility and nutrient uptake

Rasnake *et al.*, (2000) reported that poultry litter can serve as an economical source of nutrients for crop production. However, repeated use of litter lead to an accumulation of phosphorus, copper and zinc in the surface soil layer. This study indicated that applying manure to soils will supply the nutrient needs of crops. Lopez *et al.*, (2001) reported that poultry manure improved chemical and physical properties of soil and the products

obtained were ecologically healthy. Saha *et al.*, (2008) conducted a field study on the effect of combined application of in-organic fertilizer, and organic manure on the productivity, mineral nutrition and soil properties and post-harvest soil analysis showed that the soil fertility status was enriched in respect of organic carbon, available N,P and K, where inorganic fertilizer was incorporated in association with poultry manure over the 100 per cent NPK through chemical fertilizer.

Maguire *et al.*, (2006) carried out an experiment with different level of poultry litter to assess the bacteria population in soil. They reported that application of poultry litter to soil increased the bacteria population, which is also responsible for soil fertility. Shelke *et al.*, (2001) investigated the effect of farmyard manure and poultry manures and revealed that poultry manures with urea increased yield quality and the enrichment of soil nutrient N, P, K, Ca, Mg, Cu and Zn.

Addition of organic manures can compensate the detrimental effects on soil health due to injudicious application of chemical fertilizers. Whereas, excessive application of chemical fertilizers suppresses the soil productivity and harm the environment. Therefore, integrated nutrient management practices are well suited but need to be quantified either 25 or 50 per cent on equivalent basis. Further, suitability of organic manures can be based on local availability or trial based for precise results as soil types and environment play as a major factor and varies from place to place.

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