Global Scientific JOURNALS

GSJ: Volume 9, Issue 2, February 2021, Online: ISSN 2320-9186
www.globalscientificjournal.com

Integrated Nutrient Management in Rice- A Critical Review

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Critical Review Article

Abstract

Rice (*Oryza sativa L.*) is a staple food for nearly half of the world's population. Being an agricultural commodity it is the third-highest worldwide produced commodity after sugarcane and maize. At present the current world population is 7.3 billion which is expected to reach 8.5 billion by 2030. As a result the global demand towards grain is projected to double but the challenge to achieve even higher rice production level still remains. In order to meet the global demand of the growing population, rice production must be substantially increased with the adoption of the concept of Integrated Nutrient Management (INM) which must be given top-most priority. Integrated nutrient management is the maintenance or adjustment of soil fertility, plant nutrient supply to an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner. This concept is of very much importance since it involves the use of inorganic fertilizers along with organic sources that are applied to soil for increasing the quality and yield of plants in a sustainable manner without harming the natural ecosystem. With the use of integrated nutrient management in rice it has increasingly improved the overall respondents on the grain crop which leads to maximum growth characteristics and yield attributes.

Keywords: Rice, Integrated Nutrient Management, Population, Sustainable, Growth Characteristics, Yield Attributes

Introduction

Rice (*Oryza sativa L.*) is a cereal grain which is a staple food for nearly half of the world's population. It is an agricultural commodity which is having the third-highest worldwide production after sugarcane and maize (FAOSTAT, 2017). In 2018, global production of rice was 759.6 million tonnes (Mt) as compared to 2014 with just production capacity of 740 Mt FAOSTAT, 2016). India is the world's second largest rice producer (177 Mt) after China (211 Mt), with an area of 44 million hectares. India is having an average rice productivity of 2.78 t/ha^{-1} (Agriculture Statistics at a Glance, 2018). The current world population is 7.3 billion which is expected to reach 8.5 billion by 2030, 9.7 billion in 2050 and 11.2 billion in 2100 (UNSD, 2015) as a result the global demand towards grain is projected to double by 2050 and the challenge to achieve even higher rice production level still remains. With the ever-increasing need for food to satisfy the growing population, rice production must be increased significantly. The increasing demand for rice grain production has to be achieved by using an integration of organic and inorganic fertilizer to maintain the sustainability in crop production. Therefore, more efforts are needed to identify the improved nutrient management strategy for a particular target environment. Appropriate combinations of organic and inorganic nutrient sources enhance the use efficiency of nutrients and ultimately increased the growth and yield attributes of rice. In order to increase rice production for meeting the daily needs of the growing population, the concept of Integrated Nutrient Management (INM) must be given top-most priority. Integrated nutrient management is the maintenance or adjustment of soil fertility, plant nutrient supply to an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner (Roy, 1995). INM through the use of inorganic fertilizers along with organic sources are applied to soil for increasing the status of plant available nutrients and improving the physico-chemical and biological properties of soil which directly affect soil fertility (Sannathimmappa *et al*., 2015). Augmentation of soil resources is a pre-requisite for sustaining soil nutrients, to produce higher crop yield with optimum input level (Dahiphale *et al*., 2003). The combined use of chemical fertilizers along with various organic sources is capable of improving soil quality and higher crop productivity on long term basis (Baradhan and Suresh Kumar, 2018). The most logical principle for controlling the long-term fertility of soil as well as its productivity is following the concept of integrated nutrient supply systems (Rao *et al*. 2017). Usage of chemical fertilizers and organic manures has been found promising in arresting the decline trend in soil health and productivity through the correction of marginal deficiencies of primary and secondary nutrients, fauna and micro-flora and their beneficial influence on physical, chemical and biological properties of soil. Integrated nutrient management system can bring about equilibrium between degenerative and restorative activities in the soil eco-system (Upadhyay *et al*. 2011). Fertilizer use is one of the major factors for the continuous increase in rice production; more than 20 percent of fertilizer nitrogen (N) produced worldwide is used in the rice fields of Asia. Irrigated and rain-fed lowland rice systems account for 92 percent of total rice production and nutrients applied as fertilizers account for 20 – 25 percent of total production costs in these rice systems. Of the total 172.2 Mt fertilizer (N + P_2O_5 + K_2O) consumed globally during 2010 – 11, 14.3 percent (24.7 Mt) was used in rice fields. Percentages for N, phosphorus (P) and potassium (K) were 15.4, 12.8 and 12.6, respectively (Heffer, 2013). Several studies have revealed that the use of combinations of organic and inorganic fertilizers results in a consistent supply of nutrients by which the maximum plant height was obtained. (Ram *et al*. 2020) revealed that yield improvements with INM were due to instantaneous and rapid supply of nutrients through chemical fertilizers and steady supply through mineralization of FYM for prolonged period. The application of organics along with chemical fertilizers perhaps minimizes the loss of N and increases its availability throughout the crop growing period through formation of organic-mineral complexes. Also Khursheed *et al*. 2013 found that rice grain yield increased by 10.9, 21.8 and 28.5 percent respectively through conjunctive use of farm yard manure, vermi-compost and poultry manure with NPK as compared to no manure treatment and NPK alone. INM practices can be adopted by replacing 25-50 percent chemical fertilizers with organic manures to improve soil health and maintain sustainable yields in rice. In general through the utilization of various INM practices towards increasing rice production, it has a great potential of significantly benefiting rice production systems by means of increased yield and other attributes for the meeting the global demand of food. The present chapter relates to the aspects' in relation to integrated nutrient management in rice which is critically being reviewed.

Integrated Nutrient Management and its Concept

The maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner. Integrated nutrient management, developed on the principles of eco-friendly and efficient balanced fertilization and based on optimization of nutrient supplies from all the available sources, inorganic and organic, for pre-defined yield targets of the crop through an efficient combination of soil, water, organic matter etc. INM is a system that helps to restore and sustain crop productivity and also assist in checking the emerging micro-nutrient deficiencies.

Objectives of INM

The objectives of integrated plant nutrient management are:

- To increase the availability of nutrients from all sources in the soil during growing season.
- To reduce the inorganic fertilizer requirement.
- To match the demand of nutrients by the crop and supply of the nutrients from all sources.
- To optimize the functioning of the soil biosphere with respect to specified function.
- To minimize the losses of nutrients to the environment through volatilization, denitrification, surface runoff and leaching beyond the rooting zone.

Need of INM

- Decline in productivity of the crop due to decrease in effective nutrient supply.
- Poor utilization of the nutrients by the crop.
- Accelerated appearances of P, S and Zn deficiencies associated with more N fertilizer use.
- On acute P-deficient soils, N application alone depresses Decline in SOM associated with continuous application of nitrogen fertilizer.
- Accentuation of soil acidity by continuous application of acid forming fertilizers.
- Changing land use pattern from the forest ecosystem to agro ecosystem is responsible for depletion in SOM, impoverishment of soil fertility.

Components of INM:

The major components of integrated nutrient management are:

i. Integration of soil fertility restoring crops like green manures, legumes etc.
ii. Recycling of crop residues.
iii. Use of organic manures like FYM, compost, vermicompost, biogas, slurry, poultry manure, bio-compost, press mud cakes, phosphor-compost.

iv. Utilization of Bio fertilizers.
iv. Efficient genotypes and lastly.
v. Balanced use of fertilizer nutrients as per the requirement and target yields.

A. Growth Characters

i. Plant Height (cm)

Mhaske *et al.* (1997) noted higher plant height with the application of FYM @ 12 t ha^{-1} compared to no FYM application.

In a comprehensive study conducted by Maiti *et al.* (2006) the maximum plant height was recorded when the crop received 125 % RDF along with 5 tonnes of FYM ha^{-1}.

In a study of INM the plant height of rice was significantly higher due to the integrated application of biofertilizers and organic manure in combination with chemical fertilizer (Singh *et al.,* 2012).

INM results in higher plant height having longer leaves than chemical fertilizers alone attributing to enhanced seed quality parameters viz. germination rate and vigor index (Singh *et al.,* 2013).

Mahmud *et al.* (2016) reported that through application of medium level of chemical fertilizer (100 kg ha^{-1} N, 16 kg ha^{-1} P, 66 kg ha^{-1} K, 12 kg ha^{-1} S) with 4 t / ha^{-1} vermicompost gave highest plant height.

The height of the rice plants is significantly influenced with increase in N level. The maximum height of the plants was recorded in crop receiving 100% recommended dose of N (Shankar *et al.,* 2020). Similar observations on the effect of different proportion of organic manures and chemical fertilizer mixture on influencing height of the rice plants were also noted by several researchers (Kumar *et al*., 2010; Babar and Dongale, 2011; Singh *et al*., 2018).

Ajay *et al.* (2020) reported that 100 percent NPK through inorganic fertilizers + 6.25 t / ha^{-1} dhaincha application recorded highest plant height of rice at harvest stages (135.5 cm) which was comparable with 100 percent NPK through inorganic fertilizers + 5 t vermicompost (134.9 cm) and 100 percent NPK through inorganic fertilizers + 12.5 t farmyard manure (134.6 cm).

Naveen *et al.* (2021) in a study mentioned that the highest plant height in their study was recorded with M3-Furrow Irrigated Raised Beds (FIRB) along with application of S6 (100% NPK + 25% (FYM)) which was significantly higher than rest of the treatments under study.

ii. Dry matter production

Dry matter of rice increased with the supply of N either through inorganic form (50 kg N ha^{-1}) or through combination of organic (10 t FYM ha^{-1}) and inorganic sources (25 kg N ha^{-1}) as compared with organic source alone @ 20 t FYM ha^{-1} on sandy clay loam soil of Kharagpur (Ghosh *et al.,* 1994).

Mandal *et al.* (1994) observed that while increasing the nitrogen dose even by 150% of the recommended level it ultimately increased the dry matter accumulation.

Few studies have shown that, organic manures with associate adequate quantity of chemical N fertilizers may manufacture higher dry matter yield than those of conventional inorganic N fertilizers treatments (Singh *et al*., 1994 and Chung *et al*., 2000).

Sharma and Sharma (2002) observed that the increase in organic carbon content in treatments with combination of both organic and inorganic sources may be attributed to higher biomass addition to soil through crop residues.

Priyanka *et al.* (2013) in a study reported that the dry matter accumulation was highest with the application of FYM @ 20 t/ha and was followed by FYM application @ 10 t/ha and lowest dry matter accumulation was observed when no FYM was applied which may be due to the FYM provides better growing condition to plants by continuous supply of nutrients and improvement of soil properties.

The crop having 50% recommended dose of fertilizer (RDF) + 50% recommended dose of nitrogen (RDN) through mustard oil cake (MOC) and 75% RDF + 25% RDN through MOC + biofertilizer significantly increased dry matter accumulation (DMA) at initial and vital period of grain growth over those of 25% RDF + 75% RDN through MOC and 100% RDN through MOC (Mondal *et al.*, 2015).

Geetha *et al.* (2020) is a study reveals that among the treatments tested, treatment T9 (125% RDF + FYM @ 6 t ha^{-1} + biofertilizers @ 12.5 kg ha^{-1} + foliar spray of 19:19:19 (1%) at 45, 60 & 75 DAS) recorded the maximum dry matter production at harvest stage (55.35 g/ plant).

Rao *et al.* (2020) reported that nutrient management practices significantly affected dry matter accumulation with the application of T10 (125% RDF+ 25% V.C.) which was closely followed with T9 (125% RDF+ 25% FYM) in dry matter accumulation.

iii. <u>Tiller Number</u>

On sandy loam soils at Ludhiana (India), incorporation of wheat straw and FYM @ 67 and 12 t / ha^{-1}, respectively it gave higher tiller per unit area (Maskina *et al.*, 1987).

Relatively more number of tillers per hill was observed with the application of poultry manure @ 15 t ha^{-1} compared to FYM application @ 5 t ha^{-1} (Budhar *et al.*, 1991).

Increase in number of tillers per hill was observed with increasing levels of nitrogen (Shashikumar *et al.*, 1995).

Sarawgi and Sarawgi (2004) found that higher level of nutrients (50:50:40 kg NPK ha^{-1} + nitrogen blended with FYM) recorded significantly higher number of tillers $plant^{-1}$ when compared to lower levels of nutrients (25:40:30 kg NPK ha^{-1} either with or without blending with FYM).

Satyanarayana *et al.* (2002) showed that application of farmyard manure at 10 t / ha^{-1} increased tiller numbers subsequently.

Umar *et al.* (2007) revealed that NPK + GM + Zn (Soil application) (T7) gave the highest number of tillers m^{-2} (315.0), which differed from all other treatments except NPK +FYM+ Zn (soil) (T6) NPK + FYM + Zn (R.D) (T9), and NPK + GM + Zn (R.D) (T10) . The lowest number of tiller m^{-2} (181.7) was recorded for control (T1) that differed significantly from all other treatments.

Arif *et al.* (2014) concluded that maximum number of effective tillers per hill was recorded with application of poultry manure @ 10 t ha^{-1}+ 50% RDF (75:45:30 kg NPK ha^{-1}). It was statistically at par with application of FYM @ 10 t ha^{-1} and compost @ 5 t ha^{-1} along with 50% RDF and significantly superior over 100% RDF.

With the application of FYM @ 20 t ha^{-1} the number of tillers m^{-2} were significantly influenced and the least was seen with the application of FYM @ 10 t ha^{-1} (Priyanka *et al.,* 2013). Application of RDF (80:60:40 kg NPK ha^{-1}) along with FYM @ 5 t ha^{-1} showed relatively higher number of tillers than 50% RDF with FYM @ 10 t ha^{-1} (Wahland *et al.*, 2015).

Shalini *et al.* (2017) observed that application of vermicompost 1.5 t ha^{-1} + brown manuring of dhaincha @ 25 kg ha^{-1} + RDF resulted in significantly higher number of effective tillers m^{-2} over RDF (120:60:40 kg NPK ha^{-1}).

Siddaram *et al.* (2017) studied the effect of FYM on growth of aerobic rice and documented that application of FYM 12.5 t + bio-digester liquid manure equivalent to 150 kg N ha^{-1} produced significantly more number of tillers over control.

Adhikari *et al.* (2018) observed that total number of tillers $plant^{-1}$ decreased progressively with decreasing levels of nitrogen and became the least when no nitrogen was applied. Application of higher level of N (180 kg ha^{-1}) produced more number of tillers as compared to application of 150 kg of N ha^{-1}.

Kipgen *et al.* (2018) concluded that varying the nitrogen levels influenced the growth characteristics of rice application of 140 kg N ha^{-1} produced significantly higher number of tillers m^{-2} which was statistically at par with 120 kg N ha^{-1}.

More number of tillers $hill^{-1}$ was obtained with integrated use of organic and inorganic sources i.e., 50% RDF + 50% N through FYM which being significantly superior over control (Singh *et al.,* 2017). A similar significant effect was reported by Harikesh *et al.* (2017). Significantly higher number of $tillers^{-2}$ was recorded with application of 75% NPK + 25% FYM which was statistically at par with 100% NPK application (Tomar *et al.,* 2018).

B. Yield Attributes

i. <u>Number of panicles per square meter</u>

In 2008 maximum number of panicles per square meter area was noted in plants treated with 2 ton/ha organic fertilizer (329.58), it was followed by organic fertilizer in combination with NPK (326.27) and 2.5 ton/ha organic fertilizer (324.81) and minimum of that was for 0.5 ton/ha organic fertilizer (310.57), whereas control plants showed 306.17 as an average panicle number in said unit area, but in 2009 the utmost panicles per square meter area was noticed for organic fertilizer 1.5 ton/ha + NPK (343.28), afterward plot treated by organic fertilizer 2 ton/ha (341.04) then plot treated with organic fertilizer 2.5 ton/ha (335.69), and the minimum amount of panicles per square meter area was for 0.5 ton/ha organic fertilizer (327.63), although control plants showed 308.50 panicles (Siavoshi *et al.,* 2011).

Hasanuzzaman *et al.* (2010) reported that maximum panicle m^{-2} was obtained when 50% NPK was applied along with poultry manure @ 4 t / ha^{-1}.

Gohain (2014) reported that with increasing levels of nitrogen the number of panicles/m^2 significantly increased at highest level of 120 kg N/ha which was registered with the maximum number of panicles/m^2 (444.19) that might be due to increased accumulation of photosynthetic from the source to the sink.

ii. Panicle Length

Application of FYM at 5 t ha^{-1} resulted in greater panicle length in rice compared to each counterpart treatment having the same NPK levels [T1 = control (N0P0K0); T2 = nitrogen (N)–phosphorus pentoxide (P_2O_5)–dipotassium oxide (K_2O) at 30:15:15 kg ha^{-1}; T3 = N–P_2O_5–K_2O at 30:15:15 kg ha^{-1} + farmyard manure (FYM) at 5 t ha^{-1} (oven-dry weight basis); T4 = N–P_2O_5–K_2O at 60:30:30 kg ha^{-1}; T5 = N–P_2O_5–K_2O at 60:30:30 kg ha^{-1} + FYM at 5 t ha^{-1}; T6 = N–P_2O_5–K_2O at 90:45:45 kg ha^{-1}; T7 = N–P_2O_5–K_2O at 90:45:45 kg ha^{-1} + FYM at 5 t ha^{-1}] (Choudhary, Thakur, and Kumar 2007).

Hussain *et al.* (2012) reported that yield attributes viz., panicle length were significantly higher with application of RFD + poultry manure @ 20 t ha^{-1}, whereas grains $panicle^{-1}$ and panicles m^{-2} were significantly higher with application of FYM @ 20 t ha^{-1} + 75% recommended fertilizer dose.

Green manuring along with application of 50% RN (40 kg N ha^{-1}) resulted in maximum panicle length (Aulakh *et al.*, 2016).

The effect of fertilizer doses on the length of panicle was non-significant. However, it was recorded highest (28.93 cm) in F2 (100% RDF + 5 t ha^{-1} FYM (Apon *et al.*, 2018).

iii. Number of grains per panicle

Satyanarayana *et al.* (2002) observed that application of farmyard manure significantly improves number of filled grains per panicle. The number of filled grains was increased by 9% due to application of farmyard manure (72.30) when compared to no farmyard manure at 68.50.

Combination of FYM along with inorganic fertilizers increases panicle number per hill, grain number per panicle (Naing Oo, 2010).

C. Yield

i. Grain Yield

Acharya *et al.* (1998) pointed out that the application of N, P, and K fertilizer along with FYM increased the growth attributes, yield components and grain yield of rice compared with that of N, P and K through fertilizer alone.

Singh *et al.* (1998) reported that in a field experiment in 1994-1995 in Uttar Pradesh rice was given 07 t/ha FYM and 75, 100 and 125% recommended NPK fertilizer rate (100 kg N + 50 kg P_2O_5 + 50 kg K_2O/ha), grain yield were highest with 7.5 t FYM (5.59 t/ha) and the highest NPK rate (5.53 t).

Mann and Ashraf (2000) found that the maximum paddy yield could be obtained by either applying recommended dose of inorganic N fertilizer (80 kg ha^{-1}) or lowering its level to 40 kg ha^{-1}, when supplemented by green manure, dhaincha (Sesbania aculeata).

Jayabala and Kuppuswamy (2001) concluded that application of 50% N through vermicompost + 50% N through chemical fertilizers and biofertilizers led to record higher grain yield of rice.

Kumar *et al.* (2002) obtained comparable yields with the application of either 10 t FYM/ha or 2.5 t/ha vermicompost than that of 100% RDF (100:50:50 kg N P_2O_5 K_2O/ha) alone in scented rice (cv. Pusa Basmati 1).

Barik *et al.* (2008) concluded that combined application of 40% recommended dose of N as vermicompost + 60% recommended dose of N as urea produced the higher grain yield (52.7 q/ha) as compared to 100% recommended dose of N alone through urea at Mohanpur (W.B.) in transplanted *kharif* rice.

Raul and Sarawagi (2005) reported that grain yield, N content and recommended dose of N blended with FYM and 100% RDN +5 t/ha FYM were better than other treatment on pooled data basis.

Chaudhary and Thakur (2007) reported that the application of FYM in conjunction with chemical fertilizers had stimulatory effect on yield irrespective of crops and season and the highest rice grain yield was registered when 50% N was supplied through green manure in conjunction with 50% NPK through inorganic fertilizers.

In a study on the efficacy of different organic manure and inorganic fertilizer on the yield and yield attributes of Boro Rice. The maximum number of total grain plant^{-1} (97.45 was recorded from application of 70% NPKS + 2.4 tonnes poultry manure ha^{-1} (Hossaen *et al.,* 2011).

Application of enriched compost @ 2.5 t/ha gave the highest grain yield (2.45 t/ha) and it also enhanced the other quality parameters of the grain (Bora *et al.,* 2013).

ii. <u>Straw Yield</u>

Ahmad *et al.* (2005) reported that the increase in straw yield was with higher nutrient levels.

Higher straw yields of rice was seen with the application of FYM + Neemcake equivalent to 90 Kg N/ha in both the years than that of other treatments including application of 100% RDF (90 Kg N + 40 Kg P2O5 + 40 Kg k2O /ha) (Kumar *et al.,* 2005).

Gupta *et al.* (2006) reported that INM in maintaining the sustainable straw yield of rice-wheat system in rainy season without degradation of soil health under irrigated production system attained highest productivity of 33.12 kg ha^{-1} compared to other fertilizer treatments i.e., 50%, 75% and 100% NPK with substitution of 50% N by green manure with sunhemp.

The increase in fertility level from 50 to 100 % of recommended dose increased the straw yield of the crop significantly (Mankotia, 2007).

Patnayak *et al.* (2007) revealed that 40 kg inorganic N (50% N dose) integrated with biofertilizers (Azotobacter, Azospirillum and Azolla) and 17.5 kg of P and 32 kg of K ha^{-1} resulted in the highest straw yield (4.32 t ha^{-1}) of rice.

Virdia and Mehta (2010) studied the effect of integrated nutrient management in transplanted rice with treatments comprising various quantity of press mud, FYM and RDF. They found that straw yield was significantly higher with integrated nutrient management (press mud @ 20 t ha^{-1} + RDF), which remained at par with press mud @ 15 t ha^{-1} + RDF or FYM @ 10 t ha^{-1} + RDF.

Mehdi *et al.* (2011) found that different combinations of organic manures with chemical fertilizers increased straw yield significantly over application of organic manures alone. Among different combinations, Sesbania at 20 ton ha^{-1} + 75% recommended dose proved to be the best combination followed by Sesbania 20 t ha^{-1} + 50% R.D.

Balasubramanian and Wahab (2012) observed that straw yields were favorably influenced by combined application of inorganic fertilizers and organic manures.

In a study conducted by Singh *et al.* (2012) reported that application of 100% RDF through inorganic fertilizers being on par with 50% RDF as inorganic fertilizers + 50% RDN as farm yard manure but produced significantly straw yield (2.23 t ha^{-1})over rest of the fertility treatments.

Sharma and Subehia (2014) revealed that through continuous substitution of 50% N through green manure in rice produced maximum straw (7.37 t ha^{-1}) yield was 16.8 percent higher over 100% NPK added through chemical fertilizers.

D. Nutrient uptake

Murali and Setty (2001) observed that application of vermicompost at 5 t ha^{-1} combined with NPK at 150-75-75 kg ha^{-1} recorded maximum total nitrogen uptake (168 kg ha^{-1}) as compared to no vermicompost treatment (1152 kg ha^{-1}).

Mhaskar and Thorat (2005) in a study on the effects of different nitrogen levels (0, 40, 80 and 120 kg N/ha) on the N, P and K uptake of scented rice cultivars reported that N, P and K uptake was significantly influenced by the cultivar. Indrayani registered the maximum uptake of N, P; Sugandha was significantly inferior to all the cultivars. The different levels of N had significant effect in augmenting the uptake of N, P and K nutrients. Application of 120 kg N/ha recorded significantly higher N, P and K uptake in rice compared to the rest of the N levels.

Maximum mean nitrogen uptake (94.9 kg ha^{-1}) was recorded under combined use of farm yard manure and poultry manures. Incorporation of organic manures caused improvement in organic carbon and available nitrogen content of soil after crop harvest as compared to control (Kumar *et al.,* 2006).

Banik and Sharma (2008) reported that nutrient uptake in rice under the integrated nutrient management system was greater due to greater biomass production and greater nutrient mineralization from organic sources. Increase in fertilizer levels significantly increased the N uptake in rice (Choudhary and Suri 2009). Similar trends were also observed for P and K uptake in rice crop through crop residue management and chemical fertilizers as well (Choudhary and Suri 2009).

Various integrated nutrient management affected significantly nutrient uptake by rice. The maximum NPK uptake was recorded by the application of 75% NPK + 25% FYM through inorganic and organic fertilizer which was at par with 100%NPK. Availability of nutrients might be sufficient & it led to higher nutrient uptake. Minimum nutrient uptake was recorded where 50% NPK + 50% FYM) was applied. It might be due to inadequate availability of nutrient. The results are in close proximity of Talathi *et al.* (2009).

Yadav *et al.* (2010) observed the efficacy of substituting fertilizer N at different proportions (25%, 50% and 75% of total N) with organic N sources (i.e., farm yard manure (FYM), green leaf manure (GLM), poultry manure and BGA) on nutrient uptake (NPK) of rice variety Sarju 52. In general, the maximum uptake of the nutrients was obtained with the application of 25% N through green manure + 75% through inorganic urea.

Siddaram *et al.* (2010) revealed that significantly higher nitrogen, phosphorus and potassium uptake (124.2, 30.6 and 93.9 kg ha^{-1}, respectively) registered with recommended dose of fertilizer (100:50:50 kg N:P:K ha-1) + 10 tonnes of FYM ha^{-1}.

Weijabhandara *et al.* (2011) reported that application of 75% RDF + biofertilizers resulted in significantly higher grain yield, uptake of N, P, K and Zn by grains and residual available N, P, Zn compared to other treatments.

Acharya *et al.* (2012) revealed that nutrient uptake of rice was highest due to integrated nutrient application than that of inorganic nutrients alone, whereas lowest value was observed with control plot where no nutrient was applied.

The higher uptake of N, P and K in crop (106.44, 16.32 and 111.86 kg/ha respectively) with post emergence application of bispyribac sodium @ 25 g a.i. kg/ha and this treatment was at par to pre-emergence application of bensulfuron methyl @60g a.i/ha + pretilachlor @600g a.i/ha (Manjunatha *et al.*, 2012).

Ranjitha and Reddy (2013) reported that higher nitrogen 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 RDF alone. Similarly, highest P and K uptake (16.6 kg ha^{-1} and 10.3 kg ha^{-1} P; 18.9 and 127.1 kg ha^{-1} K) by grain and straw was obtained by FYM @10 t ha^{-1} + 100 percent RDF, followed by 100 percent RDF and lowest was with FYM @ 10 t ha^{-1}.

The rice crop had higher NPK uptake by grain and straw being recorded with System of Rice Intensification (SRI) method as compared to the other treatment (Transplanting (S1), Drum Seeded (S3), Direct Seeded (S4) and three integrated management practices [100% NPK (F1), 75% NPK + 25% FYM (F2), 50% NPK + 50% FYM (F3)], while lower NPK uptake by direct seeded method by grain and straw, respectively. The higher nutrient uptake was attributed to the higher grain and straw yield (Tomar *et al.*, 2018).

E. Soil nutrient status

Vennila and Jayanthi (2007) observed that application of 75% RDFN + organic manure resulted in higher soil available organic carbon, nitrogen and phosphorus. Application of 75% RDFN along with 25% N as organic manure to preceding wet seeded rice had significant residual effect on yield and nutrient uptake of succeeding green gram.

Available N, P and K status of soil was also significantly affected by various treatments. Plots supplied with 5 t ha^{-1} Gliricidia over and above farmers' practice had the highest amount of available N (295.7 kg ha^{-1}) which was significantly higher than all other treatments (Das *et al.*, 2009). Again, application of 2.5 t ha^{-1} Gliricidia along with 50% RDF and bio-fertilizers, being next best treatment, significantly enhanced soils available N-status. This could be ascribed to higher N content of Gliricidia and its role in stimulating microbial activity, contribution of Azotobacter by fixing atmospheric N (Rao, 2007).

Ghosh *et al.* (2012) reported significant increase in soil nutrient availability with the application of farm yard manure (FYM @ 7.5t/ha), paddy straw (PS @ 10 t/ha) and green manure (GM @ 8 t/ha) along with inorganic fertilizer. Both microbial biomass C and mineralizable C as well as yield of *kharif* rice were increased with the addition of the organic inputs.

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