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Enhancing rice productivity through combined soil and plant application of organic and inorganic sources of nutrients: A review

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Abstract
Soil is the natural media for plant growth. Plant nutrients in soil, whether naturally blessed or artificially maintained, are a major determinant of the success or failure of a crop production system. The crop sector of Indian agriculture must bear the responsibility, above all else, of producing enough food to meet the requirements of the country's ever-growing population. The imperative need is to achieve substantially higher crop yield than the present yield levels from the narrow land resources on a sustainable basis. A sustainable crop production system with high-yield targets cannot be balanced against nutrient removal by crops unless nutrients are applied to soil. A staple food for 2.7 billion people is rice, almost half the world's population and has grown by more than half of the world's farmers. In India, rice is the most important and staple food crop for more than two third of the population. Even though there is a large area under rice cultivation; the productivity is low due to various interaction factors. The imbalance usage of fertilizers is one of the main factors responsible for the low productivity and also the use of inorganic fertilizers continuously resulted in declining of soil fertility. To obtain the better yield, farmers apply more and more fertilizers year after year due to decline in soil fertility. Use of organic manures is a must to achieve higher and sustainable rice yields. It is, however, difficult to meet the crop nutrient requirements with only bulky organic manure and there is a need for combined application of different sources of nutrients for sustaining the desired crop productivity. Integrated nutrient management (INM) improves soil fertility and crop productivity status rather than mineral fertilizers alone. Most of the research findings reviewed in this review indicated that among the integrated nutrient management combinations, application of chemical fertilizers combined with organic manures in equal proportion improved sustainable rice productivity, nutrient uptake and soil nutrient status. Use of organic manures has been found to be satisfactory in arresting the decline in productivity through correction of deficiency of major and micronutrients and influencing the physical and biological properties of soil. Integrated application of inorganic fertilizers with different sources of organic manures in different proportions has significant role to rise rice productivity, improve nutrient uptake by plants and maintain soil nutrient status in rice based cropping systems. Therefore, the review has been taken from existing literature which proved that the combine nutrient management is a method to boost the rice yield and maintain the sustainability of the production capacity of the soil.

Keywords: Soil fertility, rice, crop nutrient, fertilizers, INM and organic manure

Introduction
Rice is one of the most important and extensively grown food crops of the world and particularly in India. In Asia, more than two billion people are acquiring 60 -70 per cent of their energy requirement from rice and its derived products. In India, rice fill up an area of 44 million hectares with an average production of 90 million tonnes. Rice is having productivity of 2.0 tonnes per hectare. Demand for rice is growing day by day and it is estimated that in 2010 and 2025 AD the requirement would be 100 and 140 million tonnes respectively. To sustain current food self sufficiency of country and to meet future food requirements, India has to boost its rice productivity by 3 per cent per annum (Thiyagarajan, 2007).

Non–availability of chemical fertilizers at right time and their higher dose or cost is the reasons for creating imbalance in the soil. To maintain the soil health and provide sufficient plant nutrition, it is about the plant nutrient sources other than the chemical fertilizers and their application with combination (Singh *et al*., 2009). Due to the favourable effect on physical, chemical and biological properties of soil, use of organic manure, green manuring and crop residues integrated with inorganic fertilizers not only reduces the demand of inorganic fertilizers, but also, increases the efficiency of applied nutrients (Prasad *et al.*, 1992).

Effect of organic manures on growth and yield of Rice

Farmyard manure (FYM)

Application of farmyard manure at 10 t ha^{-1} increased significantly the number of tillers $hill^{-1}$ (14.3), number of filled grains $panicle^{-1}$ (72.3), 1000-grain weight (29.3 g), grain yield (3.8t ha^{-1}) and straw yield (4.6t ha^{-1}) of rice (Satyanarayana *et al*., 2002) [27]. Satheesh and Balasubramanian (2003) [26] observed higher agronomic efficiency with farmyard manure along with neem cake than others was (27.5 kg grain kg^{-1} N). Manjappa *et al*., (1994) [14] found sustaining soil productivity and improved nutrient use efficiency with use of organic manures in the crop. Sharma (1994) [29] noted that the grain yield and straw yield of rice increased with the increased rate of FYM. Mhaske *et al*., (1997) [16] noted higher plant height and number of tillers $plant^{-1}$ with the application of FYM @ 12t ha^{-1}over no FYM application. At CRRI, Cuttack, application of 10t FYM ha^{-1} increased the grain yield over no FYM, and the yield was comparable with 20 or 40 kg N ha^{-1}. Mirza *et al*., (2005) [17] reported that productive tillers were increased by the application of FYM but differences were non-significant between 10 and 20t ha^{-1}ofFYM application. The increases in paddy yield due to application of 5, 10 and 20t $ha^{-1}$of FYM was 6.8%, 24.4% and 37.6% compared to control.

Vermicompost

Radzi *et al*. (2017) [22] noted higher means result with the application of vermicompost with chemical fertilizer (70% vermicompost + 30% NPK) for plant height, number of leaves and yield. The positive effect of vermicompost when applied with chemical fertilizer might due to nutrients rich composition of the vermicompost. Most of the nutrients in vermicompost is in the form which taken up by plants. Rahimabadi *et al*. (2017) [23] reported that the combined effect of vermicompost × cow manure × year had significant impact on the harvest index, the grain yield, and the biological yield. 10 and 20t ha^{-1} cow manure increased the biological yield by 5.3 and 8.1% in the first year and by 4.3 and 18.1% in the second year as over control, respectively. Also, thevermicompost application of 5 and 10 t ha^{-1} increased yield by 9.0 and 17.9% in the first year and 12.3 and 24.8% in the second year. Likewise, the grain yield increased 11.26% and 52.66% in the first year and a 36.1 and 61.2% in the second year when 10 and 20t ha^{-1} cow manure was applied. The incorporation of vermicompost in soil at the rates of 5 and 10 t ha^{-1} increased grain yield by 41.4 and 69.6% in the first year and by 49.2 and 93.0% in the second year, respectively. Rate of vermicompost application at 3.0 t ha^{-1} produced taller plants (95.9 cm), leaf area index (4.9) and dry weight $hill^{-1}$ (30.3 g) than FYM at 10t ha^{-1} in rice crop. Better growth attributes was found in rice under vermicompost due to increased availability of plant nutrients (Sharma *et al*., 2008) [28].

Green manures

Islam *et al*. (2015) [9] observed that integration of all green manures (C. juncea, S. aculeata, S. rostrata, P. mungo, and V. radiata) with 120, 80, and 40 kg N ha^{-1}, and seasonal fallow in combination with 80 kg N ha^{-1}, produced significantly higher grain yields of rice. Plot treated with a 75% recommended dose of nitrogen (RDN) and green manure incorporated at 50 DAS results in highest grain yield 5752 kg $ha^{-1}$of rice (Islam *et al*., 2014) [7]. Latt *et al*. (2009) [12] documented that the plant height and tiller number of rice were significantly higher in green manure treatments than those treated with urea and treatments having no application. Such improvement in tiller number, number of panicles and yield of rice due to the beneficial effect of green manure addition has also been reported by Singh *et al*. (1990) [31].

In-situ incorporation of green manure (dhaincha) at 12t ha^{-1} increased the grain (18%) and straw (16%) yields of rice owing to increase in growth and yield attributes of rice (Vats *et al*., 2001) [35]. Bajpai *et al*. (2006) [1] recorded the highest yield of rice when 50 per cent of nitrogen was supplied through green manuring.

Poultry manure

Poultry manure is rich in nutrients and from solid and liquid excreta is excreted together, resulting in no urine loss. In fresh poultry excreta, most abundant nitrogen compound (40-70 of total N) are uric acid or urate while urea and ammonium are present in small amounts (Krogdahl and Dahlsgard, 1981) [11]. Poultry manure is a good source of nutrients *viz*., macro N, P, K, S, Ca, Mg, micro Zn, Cu, Fe and Mn (Reddy *et al*., 2003) [24]. Oyekanmi *et al*. (2009) [20] reported that NERICA 1 rice resulted in 3.2t ha^{-1} and 2.7t ha^{-1} of grain yield when incorporated with poultry manure 16t ha^{-1} and 8t ha^{-1}, respectively. Moe *et al*. (2019) [19] observed that Rice incorporated with chemical Fertilizer+Poutry. Highest yields produced by Manure 6.90 and 7.42t ha^{-1} in 2017 and 2018, respectively. In 2017, the highest HI values noted were 0.48, 0.49, and 0.49 for chemical fertilizer+poutry+manure, Chemical Fertilizer+Compost and Chemical Fertilizer+Compost plots, respectively. The highest HI values in 2018 were 0.51, 0.51, and 0.49 for plants in the same treatments.

Effect of chemical fertilizers on growth and yield of Rice

Nitrogenous fertilizers

Chaturvedi (2005) [3] revealed that application of nitrogenous fertilizers significantly increased the yield attributes, viz $grainsear^{-1}$, grain $weightear^{-1}$ and 1000-grain weight. The number of $grainsear^{-1}$ against various applications of N-fertilizers results in ammonium sulphate nitrate, produced maximum number of grains ear^{-1} (95.2 and 95.9) during 2002 and 2003 respectively. The yield data showed a positive response to N fertilizer treatment. The pooled data of yield showed that rice crop significantly responded to sulphur-containing nitrogen fertilizers over non sulphur containing nitrogen fertilizers plots. The Super Net gave significant maximum grain yield of 6.45t ha^{-1} and lowest grain yield of 4.49t ha^{-1} was obtained from the plots treated with urea. Islama *et al*. (2009) [10] reported that among the split application of N, three equal splits at 15, 30 and 55 DAT resulted highest grain yield (45.2 g $hill^{-1}$) which was 47.8 per cent higher than control. Split application of urea influenced significantly on the plant height (103.8 cm), number of leaves hill-1 (92.2) and number of tillers $hill^{-1}$ (20.7).

Phosphorus fertilizers

Singh and Singh (2008) [30] revealed that when 60 kg $P_2O_5ha^{-1}$ was added to 120 kg N ha^{-1}, it significantly increased the grain yield (5.31t ha^{-1}) compared to N 120 alone (4.7t ha^{-1}). Maximum yield of rice was observed for 150 kg ha^{-1} nitrogen fertilizer and minimum of that was observed for 50 kg ha^{-1} nitrogen fertilizer. Maximum yield was obtained for 150 kg ha^{-1} phosphorus fertilizer and minimum of that was obtained for (control) 0 kg ha^{-1} phosphorus fertilizer (Yoseftabar, 2013) [36]. Uddin *et al*. (2014) [33] reported that 40 kg P ha^{-1} resulted in highest harvest index (37.85%), in case of the

higher yield of grain and straw as well as maximum biological yield were found also under this treatment.

Potassium fertilizers

Esfehani *et al*. (2005) [4] showed that potassium fertilizer has positive impact on filled grains in rice while its deficiency caused pollen sterility and decreased in number of filled grains panicle^{-1}. Uddin *et al.* (2013) [34] revealed that the highest grain yield was noted in 40 kg K_2O ha^{-1} because of the highest number of effective tillers and maximum number of grains panicle^{-1} also produced by 40 kg K_2O ha^{-1}. The grain yield was 70.14% higher compared to control (0 kg K_2O ha^{-1}) which was lowest grain yield. Manzoor *et al*. (2008) [15] obtained a maximum value of plant height (126.6 cm), tillers hill^{-1} (20.2), panicle length (28.7 cm), number of grains panicle^{-1} (103.8), 1000 grain weight (20.9 g) and grain yield (3.3t ha^{-1}) were recorded in treatment receiving split use of potassium as ½ at 25 DAT and ½ at 45 DAT.

Effect of integrated nutrient management on growth and yield of rice

Integrated application of inorganic nutrients viz. NPK along with micronutrients and sulphur increased grain yield over only inorganically treated nutrients. So, integrated application of macro and micro-nutrients along with sulphur has a great role to increase the grain yield of rice. The micronutrients like B, Mo and Zn showed their interaction effect in conjunction with NPK on yield and yield attributeing of rice. It was also found that Azotobactor and Azospirillium treated plots recorded higher yield than only NPK treated plots of rice (Malik *et al*., 2002) [13]. Improvement in yield due to combined application of INM treatments are mainly due to balanced supply of nutrients which might have expedited better crop growth (Saha *et al*., 2007) [25]. Several authors reported the beneficial effects of Azospirillum inoculation in increasing yield of rice (Islam *et al*., 2005; Fakir *et al*., 2007) [8, 5]. Investigations showed that Azospirillum inoculation increased yield of rice significantly by 1.6–10.5 g plant^{-1} (32–81% increase) in greenhouse conditions (Mirza *et al*., 2000; Malik *et al*., 2002) [13]. However, under field conditions, the estimated yield increase was approximately 1.8t ha^{-1} (22% increase), as reported by Balandreau (2002). In rice, taller plants (115.5 cm), more productive tillers hill^{-1} (9.1), increased panicle length (20.3 cm), higher number of filled grains panicle^{-1} (178), better test weight (14.9 g) and grain yield (8.1t ha^{-1}) were obtained with combined use of daincha at 6.25t ha^{-1} and 100 kg N ha^{-1} applied at equal splits at basal, 21 DAT, panicle initiation and flowering stages than others (Parasuraman and Chandrasekaran, 2005) [21]. Tilahun *et al*. (2013) [32] observed that the combined application of 15t ha^{-1} FYM together with 120 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5results in additional 2.79 and 1.39t ha^{-1} rice grain yield compared to the negative (0-0-0 kg ha^{-1} FYM-N-P_2O_5) and positive (0-120-100 kg ha^{-1} FYM-N-P_2O_5) controls, respectively. This has yield advantages of 123% and 38% over the respective controls. The result further showed that optimum straw and grain yields of the rice were attained at the highest with combined application rates of the three fertilizers. Bodruzzaman *et al*. (2010) [2] also reported that plots with 10t ha^{-1} FYM plus 75% NPKSZn produced equivalent or higher rice yields as 100% NPKSZn. Gill *et al*., (1994) [6] reported that rice yields increased significantly with the increase in nitrogen levels up to 100 kg ha^{-1}. Rice yields still higher in 100 per cent application of N, P and K and in treatments with part of N supplied through various organic sources.

Conclusion

This review paper emphasized the importance of an integrated nutrient management which improves yield of rice, supply available plant nutrient directly to plants and created a favorable soil environment and as proper decomposition of organic matter, ultimately, increased the nutrient capacity of soil for longer time, which resulted in better growth, yield attributes and ultimately grain and straw yield. Organic manures are reported to enhance the fertilizer efficiency and reduce the requirement of inorganic fertilizers. Traditional green manures (*Sesbania aculeate*), FYM, Vermicompost, Poultry manure may serve as alternative source of nutrients to the plants and may supplement and chemical fertilizers. Integrated nutrient management was found to increase in the sustainability of the production capacity of the soil and reduce the requirement of inorganic fertilizers without curtailing the yield of rice.

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