Nutrients availability and yield of wheat under different integrated nutrient management practices in rice-wheat cropping system: A Review

Lalit Kumar[1]; Prasant Ahlawat[2]; R.I Navsare[3]; Pradeep Rajput[4]; and Pradeep Kumar Singh[4]

[1]*Indian Institute of Farming System Research (IIFSR), Modipuram, Meerut, U.P., India*
[2]*Department of Plant Pathology, C.C.S University Campus, Meerut, Uttar Pradesh, India*
[3]*Department of Soil Science & Agricultural chemistry,* [4]*Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India*

ABSTRACT

Over years of intensive cultivation and imbalanced fertilizer use, the soils of the Indian subcontinent have become deficient in several nutrients and are impoverished in organic matter. Recently, this region has started emphasizing a shift from inorganic to organic farming to manage soil health. However, owing to the steadily increasing demands for food by the overgrowing populations of this region, a complete shift to an organic farming system is not possible. The rice–wheat cropping system (RWCS) is in crisis because of falling or static yields. The nations of this region have already recognized this problem and have modified farming systems toward integrated nutrient management (INM) practices. The INM concept aims to design farming systems to ensure sustainability by improving soil health, while securing food for the population by improving crop productivity. The maximum number of effective tillers, grains per ear, ear length, test weight, grain, straw and biological yields recorded in 120 kg N + 40 kg P_2O_5 ha^{-1} fertilizer levels also proved significantly superior to lower levels of fertilizers. The growth, development, yield attributes of both rice and wheat was found to be best when 50% N through FYM and 50% NPK to rice and 100% NPK to wheat. The improvement in yield attributes and yield of crop was recorded with the application of T_4- 100% RDF + Vermicompost (2tha^{-1}) + PSB which was at par with the application of T_5- 75%RDF+Vermicompost (2tha^{-1})+PSB and T_3- 100% RDF + Vermicompost (2tha^{-1}). Therefore, there is a need to improve nutrient supply system in terms of integrated nutrient management involving the use of chemical fertilizers in conjunction with organic manures coupled with input through biological processes. However, the role of major nutrients on crop physiology and the effect of these nutrients on yield and yield components of cereal crops in general and rice-wheat in particular are unsatisfactory. The role of balanced fertilizer is the application of essential plant nutrients in light proportion and in optimum quantity for a specific soil crop condition in alleviating the yield, and its attributes of rice-wheat production is important. In association with this, research on integrated nutrient management in rice-wheat and its effect on yield, yield components and quality parameters are significance. Thus, INM approach is not only a reliable way for obtaining fairly high productivity with increased FUE but also an alternative practice towards sustainable agriculture.

Keywords: *integrated nutrient management; profitability, soil health; sustainability*

INTRODUCTION

Rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) crops are major staple foods, contributing a key portion of digestible energy and protein in human intake and occupying a premium position among all food communities (Das et al., 2014). The rice–wheat cropping system (RWCS) is one of the most prominent cropping systems prevailing on the Indian subcontinent and is considered to be of utmost importance for food security and livelihood (Mohanty et al., 2013). The RWCS occupies about 13.5 million hectares spread over the Indian subcontinent, namely, India, Pakistan, Nepal, Bangladesh, Sri Lanka, and Bhutan, and accounting for one-fourth to one-third of total food grain production (Ladha et al., 2003). This cropping system covers about one-third of the total rice cultivation and two-fifths of the total wheat cultivation in the Indian subcontinent. Currently, more than nine-tenths of global rice is produced and consumed in these nations. Natural resources, primarily agricultural lands, are limited globally. To meet the food demand of the ever-increasing population, agriculture must produce more food grains from limited cultivable land (Hobbs et al., 2008). The crop productivity of the region is low and oscillating from 0.5 t ha^{-1}

to 2.5 t ha^{-1}, with a mean of 1.5 t ha^{-1}. The increasing population and food consumption and the decline in existing arable land and other units of supply are placing exceptional pressure on the present farming system to meet the growing food demand. To counteract this problem and obtain higher yields, crop growers are shifting to fertilizer-responsive high-yielding varieties and avoiding the overuse of inputs such as synthetic fertilizers. The soils under the RWCS are now showing signs of fatigue and are no longer showing increased production with an increase in fertilizer use. Even with the use of the recommended rate of fertilizer in the RWCS, a negative balance of primary nutrients has been recorded. To obtain food security in these nations, crop yields must rise considerably while ecological effects must contract significantly (Foley et al., 2011). With the possibility of horizontal expansion or putting more land under cultivation, future augmentation in yield would have to be harnessed vertically through judicious management of all the input resources. It is well known fact that nearly 50 per cent gain in food grain productivity seen in recent times has come through fertilizers alone. In absence of fertilizer, India would have required 2-3 times more land to fill up the food grain basket (Singh and Biswas, 2002).

The productivity of rice-wheat depends upon the nutrient supplying capacity of the soil and fertilizers schedule there on. Among the major nutrients, high yielding varieties of wheat have been found highly responsive to nitrogen fertilization. However, in absence of phosphorus, nitrogen becomes ineffective and most of the applied nitrogen remains unutilized (Sharma and Tandon, 1992). Therefore, the easiest way for boosting the productivity is through use of balanced fertilization. Regular and judicious use of fertilizer not only help in raising good crop yields on a sustainable basis but can also help the farmers to gain consistency in higher profit. But even today, most of the farmers in this region are usually applying higher dose of nitrogen, low phosphorus and no potassic fertilizers at all which grossly imbalance the ratios of N, P and K. Several problems including soil fertility deterioration and environmental pollution emerging as a result of present agricultural system, are affecting the soil productivity adversely. Organic farming in many quarters is taken as a system of farming that prohibits the use of chemical fertilizers and pesticides all together. It is the well known fact that addition of organic manures has shown considerable increase in crop yield and exerts significant influence on physical chemical and biological properties of soil. But its use alone is not sufficient to meet the requirement of nutrients. Moreover, an integrated approach to plant nutrient management gained momentum and importance in recent years. The objective of this approach is efficient, judicious and economic use of all major sources of plant nutrients in an integrated manner so as to maximize/optimize yield of a crop or a cropping system without any adverse effect on the agro-ecosystem. It has therefore, becomes necessary to develop an integrated plant nutrient management system, involving the use of inorganic fertilizers on one hand and the organic manure as an organic source on the other for maximizing /optimizing rice-wheat productivity.

Therefore, one of the most promising means for increasing yield in the rice-wheat system is to develop alternative nutrient management practices, which may increase factor productivity and crop yields. In this direction, integrated management of organic manures and mineral fertilizers can be a useful practice to increase crop yields along with soil fertility. Integrated nutrient management (INM) means judicious and efficient use of mineral fertilizers, organic manures and bio-fertilizers in an integrated manner, to get the maximum productivity and maintain soil fertility.

Addition of organic manures along with chemical fertilizers sustained the yield through increased nutrients availability and nutrient use efficiency. Use of organic manures in INM helps in mitigating multiple nutrient deficiencies (Satyanayarana et al., 2002). Application of organic manures, i.e., FYM @ 10 t/ha and vermicompost 5 t/ha with 60 kg P_2O_5/ha or 40 kg P_2O_5/ha + PSB and 40 kg S/ha produced maximum wheat grain and straw yield (Patel, et al., 2014). Application of biofertilizers which is environment friendly and low cost input, with organic and inorganic fertilizers as part of an integrated nutrient management strategy and play significant role in plant nutrition (Patel et al., 2011). The role of biofertilizers is perceived as growth regulators besides biological nitrogen fixation collectively leading to much higher response on various growth and yield attributing characters (Saiyad, 2014).Thus judicious use of organic manure, biofertilizer and organic fertilizer helps in sustain production of rice-wheat system.

Integrated use of these organic manures along with chemical fertilizers enhances yield of rice up-to 20-30% and other physiological characteristics as well as better nutrient uptake (Mohanty et al., 2013; Yadav et al., 2013). Long term studies being carried out at several locations in India indicated that application of all the needy nutrients through chemical fertilizers have deleterious effect on soil health leading to unsustainable yields (Jaga, 2013). Therefore, there is a need to improve nutrient supply system in terms of integrated nutrient management involving the use of chemical fertilizers in conjunction with organic manures coupled with input through biological processes (Aulakh, 2010).

It is quite normal that increasing levels of applied N increased grain yield of wheat (Behera, 2000). Increasing N levels increased grain yield by increasing the magnitude of yield attributes. Similarly, Tayebih (2011), indicated that

the different N rates (120, 240 and 360 kg ha^{-1}) have a significant effect on grain yield increment (46% at N_{120}, 72% at N_{240}, and 78% at N_{360}) compared to control. The increase in grain yield was due to increase in the yield attribute as the level of nitrogen was increased. Channabasavanna and Setty, 1994 stated that the increase in yield attributing characters, however, was the result of better nutrition or N uptake, leading to greater dry matter production and its translocation to the sink (Dalal and Dixit, 1987). Increased productivity of wheat can be achieved by adopting improved agronomic practices and varieties (Sadat *et al*., 2008). Increasing nitrogen rates had a significant effect on the grain yield with maximum grain yield was obtained in the case of 150 kg N ha^{-1} (3.91 t ha^{-1}) while nitrogen application beyond the level of 100 kg N ha^{-1} did not increase the grain yield ha^{-1} to a significant extent (Maqsood et al, 2000) . Similar results were reported by Singh and Uttam (1992) who reported that grain yield increased significantly up to 120 kg N ha^{-1}.

Addition of organic matter in the soil is a well-known practice to increase crop yields. Organic matter like FYM has supplied available nutrients to the plants provided favorable soil environment and increase water holding capacity of soil for longer time. Singh and Tomer, (1991) reported that application of Farm yard Manure helps to increase the DMP, yield and nutrient uptake by wheat. The soil incorporation of mustard/taramira + FYM and FYM at 10 t ha^{-1}significantly increased grain yield of wheat across the years (Regar *et al*., 2005). Application of FYM @ 10 and 20 tonnes/ha increased the grain yield and the total N P and K uptake in wheat crop (Singh and Agrawal, 2005). FYM application (10tha^{-1}) resulted in a 2004 and 21.5 % increase in grain and straw yield over control respectively. Response of FYM measured as kg grain tonne-1 was highest in wheat (Mahapatra *et al.,* 2007).

According to (Fassil *et al.,* 2009) soil erosion causes several damages to the physicochemical characteristics of soil such as loss of organic matter, loss of soil fertility, decreased infiltration rate and water holding capacity, and exposure of subsoil with higher clay content and poor soil fertility. This indicates that valuable nutrients are lost every year resulting in low soil fertility. Imbalanced fertilization practiced over a long period of time and replacement of recycling of organic materials and application of organic manures in this part of the country raised concerns about the potential long-term adverse impacts on soil productivity and environmental quality. Addition of FYM with inorganic fertilizers to soil has been reported to increase the efficiency of applied fertilizers moreover; addition of FYM with inorganic fertilizers improves organic matter content of soil and consequently water holding capacity of soil (Hati *et al*., 2007). Nutrient replenishment by merely adding fertilizers is often not economically feasible and even in the technically, it may not be in balance with the supply of organic matter.

Application of N in conjunction with two organic sources i.e., FYM and wheat straw proved better than their individual application and affected economy of 50 kg N ha^{-1} for rice grain production (Rajput and Warsi, 1991). Arumugam et al. (1992) reported that rice yield obtained by 100% N (soil test lab recommendation) application were on par with 75% N combined with FYM @ 5 t ha^{-1} and Azospirillum @ 5 kg ha^{-1} and concluded that there is possible saving of 25% of fertilizer N by adopting integrated nutrient management. Datta and Banik, (1994) noticed the higher grain yields (4.28 t ha^{-1}) of rice were obtained with the application of poultry manure @ 5 t ha^{-1} compared to other treatments involving organics.

Kumar et al. (2017) reported that application 75% RDF as inorganic fertilizers along with green manuring of dhaincha in-situ incorporated in alternate year recorded significantly higher values of growth and yield attributes over rest of the treatments except 100% RDF as inorganic fertilizers. This treatment also recorded significantly highest grain and straw yield (45.04 and 72.0 q ha^{-1} respectively) followed by 75% RDF as inorganic fertilizers along with green manuring of sunhemp in-situ incorporated in alternate year's and100% RDF.

Budhar et al (1991) reported that there was higher amount of residual N in plots treated with poultry manure, FYM, biogas slurry @ 5 t ha^{-1} and sesbania @ 12.5 t ha^{-1}. Similarly, they also observed that P and K status of soil was higher in poultry manure @ 5 t ha-1, pongamia and sesbania plots. Continuous addition of FYM along with NPK fertilizers resulted in higher available N and P, while addition of compost along with K fertilizer recorded higher available K content in soil (Udayasoorian and Paramasivam, 1991). Similarly, application of FYM and compost @ 25 t ha-1 increased available K content of soil (Udayasoorian et al., 1989). Udayasoorian and Sreeramulu (1991) reported that continuous manuring and fertilization resulted in less depletion of inorganic P fractions. Bhandari et al. (1992) observed that the NPK fertilizers at 100% recommended levels or more and their combined use with organic N sources also increased the available N and P by 5 – 22 kg and 0.8-3.8 kg ha^{-1} respectively from their initial values in a rice wheat sequence. Selvi and Ramaswami, (1995) revealed in a rice-rice-pulse sequence effect of NPK plus organics particularly FYM significantly increased the available N, P and K contents of soil. Yadvinder Singh et al. (1995) noticed that fertilizer N equivalents in rice ranged from 42 to 52% of the total N applied and the apparent N recovery was 20% from FYM as compared with 35 to 46% in urea. Moreover, the N mineralization in soil from poultry manures containing narrower C: N ratio is substantially faster than from FYM (Yadvinder Singh et al., 1988).

CONCLUSIONS

This review paper emphasized the role and importance of an integrated nutrient management system as a management strategy that can bring sustainability to the rice–wheat cropping system of the Indian subcontinent. The net returns through integrated nutrient management treatment were increased by 121% and 127% in rice and wheat, respectively, compared to control. An integrated use of chemical and organic fertilizer has proved to be highly beneficial for sustainable crop production. Several researchers have demonstrated the beneficial effect of combined use of chemical and organic fertilizers to mitigate the deficiency of many secondary and micronutrients in fields that continuously received only N, P and K fertilizers. Addition of FYM with inorganic fertilizers to soil has been reported to increase the efficiency of applied fertilizers moreover; addition of FYM with inorganic fertilizers improves organic matter content of soil and consequently water holding capacity of soil. Nutrient replenishment by merely adding chemical fertilizers is often not economically feasible and even in the technically, it may not be in balance with the supply of organic matter. It is commonly believed that the combination of organic and inorganic fertilizer will increase synchrony, enhancing the efficiency of the fertilizers, and reduce losses by converting inorganic nitrogen (N) into organic forms but also reducing environmental problems that may arise from their use. The findings of the present review suggested that INM can be one of the viable nutrient management options in the Indian subcontinent, particularly for the rice–wheat cropping system.

REFERENCES

- Arumugam, M., Raja Gopalam, S., Ramakrishnan, S and Rangaswamy, M. (1992). Effect of integrated nutrient management on rice yield. Oryza , 1992,29: 155-156.
- Aulakh, M.S. Integrated nutrient management for sustainable crop production, improving crop quality and soil health, and minimizing environmental pollution. 19th World Congress of Soil Science, Soil Solutions for a Changing World, 1–6 August 2010, Brisbane, Australia
- Behera, U.K., B.A. Chougule, R.S. Thakur, K.N. Ruwali, R.C. Bhawsar and H.N. Pandey, 2000. Influence of planting dates and nitrogen levels on yield and quality of durum wheat (*Triticum durum*). *Indian J Agri Sci*, 2000, 70: 434-436
- Bhandari, A. L., Anil Sood, Sharma, K. N and Rana, D. S. Integrated nutrient management in rice-wheat system. JIndian Soc Soil Sci., 199, 40: 742-747.
- Budhar, M. N., Palaniappan, S. P and Rangaswamy, A. Effect of farm wastes and green manures on low land rice. Indian JAgron., 1991, 36 (2): 251-252.
- Channabasavanna, A.S. and Setty, R.A. Response of Broadcast Rice Level of Nitrogen, Phosphorus and Time of N Application. *Indian J.Agron*. 1994. 39 (30):457-459.
- Dalal and Dixit. Response of Newly Developed Medium Duration and Yielding Cereal Genotypes to Nitrogen .*Indian J.Agron*. 1987, 30:114-116.
- Das, A.;Sharma, R.P.; Chattopadhyaya, N.; Rakshit, R. Yield trends and nutrient budgeting under a long-term (28 years) nutrient management in rice-wheat cropping system under subtropical climatic condition. Plant Soil Environ. 2014, 60, 351–357
- Datta, M and Banik, S. Effect of poultry manure and phosphate dissolving bacteria on rice (*Oryza sativa*) in acid soil. Indian J Agri Sci., 1994, 64 (1): 791-793.
- Fassil Kebede and Charles Yamoah. Soil Fertility Status and Numass Fertilizer Recommendation of Typic Hapluusterts in the Northern Highlands of Ethiopia, World Applied, Sci., J, 2009, 6 (11): 1473-1480,
- Foley, J.A.; Ramankutty, N.; Brauman, K.A.; Cassidy, E.S.; Gerber, J.S.; Johnston, M. Solutions for a cultivated planet. Nature 2011, 478, 337–342.
- Gomez KA, Gomez AA. Statistical procedures for agricultural research 2nd Edition. John Willey and Sons, New York. 1984; 680
- Hati, K.M., A. Swarup, A.K. Dwivedi, A.K. misra and K. K. Bandyopadhyay.Changes in soil physical properties and organic carbon status at the topsoil horizon of a vertisol of central India after 28 years of continuous cropping, fertilization and manuring. *Agri, Ecosyst Environ, 2007,* 119 (1-2):127-134
- Hobbs, P.R.; Sayre, K.; Gupta, R. The role of conservation agriculture in sustainable agriculture. Philos. Trans. R. Soc. B Biol. Sci. 2008, 363, 543–555.
- Jaga, P.K. Effect of integrated nutrient management on wheat – a review. Innovare J Agri Sci, 2013, 1(1): 185-191.
- Kumar, V., kumar, T., singh, G., and Singh, R.A. Effect of integrated nutrient management on yield of rice and its residual effect on wheat in rice-wheat system under lowland, Ann Plant Soil Res, 2017, 19(4): 360-365.

- Ladha, J.K.; Dawe, D.; Pathak, H.; Padre, A.T.; Yadav, R.L.; Singh, B.; Singh, Y.; Singh, Y.; Singh, P.; Kundu, A.L.; et al. How extensive are yield declines in long-term rice-wheat experiments in Asia? Field Crops Res. 2003, 81, 159–180
- Mahapatra P.,Singh R.P. , Singh,B.P. and Sarkar, A.K. Long term effects of fertilizer, organic manure & amendments on soil health, crop productivity and sustainability. SSAC (BAU) *Technical Bulletin, 2007, 4:* 1-75
- Mohanty, S.; Nayak, A.K.; Kumar, A.; Tripathi, R.; Shahid, M.; Bhattacharyya, P.; Raja, R.; Panda, B.B. Carbon and nitrogen mineralization kinetics in soil of rice–rice system under long term application of chemical fertilizers and farmyard manure. Eur. J. Soil Biol. 2013, 58, 113–121.
- Mohanty, M., S.S. Nanda and Barik, A.K. Effect of integrated nutrient management on growth, yield, nutrient uptake and economics of wet season rice (Oryza sativa) in Odisha. Indian J Agri Sci, 2013, 83(6): 599-604.
- Patel BN, Solanki MP, Patel SR, Desai JR. Effect of bio-fertilizers growth, physiological parameters, yield and quality of brinjal cv. Surti Ravaiya. Indian J Horti. 2011, 68(3):370-374.
- Patel HK, Sadhu AC, Lakum YC, Suthar JV. Response of integrated nutrient management on wheat (*Triticum aestivum* L) and its residual effect on succeeding crop. Int J Agri Sci & Vety Medi. 2014; 2(4):48 -52
- Rajput, A. L and Warsi, A. S. Contribution of organic materials to nitrogen economy in rice *(Oryza sativa*) production. Indian J Agro. 1991, 36 (3): 455-456.
- Regar,P.L. Rao,S.S and Vyas, S.P. Crop-residue management for increased wheat (*Triticum aestivum*) production under saline soils of arid fringes. *Indian J Agri Sci., 2005, 75(2):* 83-86.
- Sadat, M.N, Rahman, M.A, Miah, M.N.A., Ara, M. I. and Al Azad, M. A. K. (2008), Effect of split application of nitrogen on yield and grain protein content of wheat. *Bangladesh Res. Pub J.2008k,* 1(4): 285-296.
- Saiyad MM. Effect of liquid biofertilizers on yield attributes of brinjal (*Solanum melongena* L.). Trends in Biosciences. 2014; 7(22):3754-3756.
- Satyanarayana V, Prasad PVV, Murthy VRK, Boote KJ. Influence of integrated use of farm yard manure and ignoring fertilizers on yield and yield components on irrigated lowland rice. J plant nutr. 2002; 25(10):2081-2090.
- Selvi, S and Ramaswami, P. P. Residual effects of Integrated Nutrient Management in Rice-Rice-Pulse cropping sequence. Madras Agri J., 1995, 82 (1): 26-28.
- Sharma, P.K. and Tandon, H.L.S. 1992. In: Management of nutrient interaction in agriculture (Ed. HLS, Tandon) FDCO, pp. 1-20.
- Singh, V.P. and S.K. Uttam. Response of wheat cultivars to different nitrogen levels under sown conditions. *Crop Res., Hisar. 1992,* 5: 82–86.
- Singh,R and Agrawal, S.K. (2005) Effect of levels of farm yard manure and nitrogen fertilizer on grain yield and use efficiency of nutrients on wheat (*Triticum aestivum*). *Indian J Agri Sci.,2005, 75(7):408-413*
- Singh, G.B. and Biswas, P.P. 2000. Balanced and integrated nutrient management for sustainable crop production. Fertilizers News. 45: 55-60.
- Tayebeh Abedi,Abbas Alemzadeh, Seyed Abdolreza Kazemeini. Wheat Yield and Grain Protein Response to Nitrogen Amount and Timing. *Aust J Crop Sci., AJCS* 5(3):330-336 (2011)
- Udayasoorian, C and Paramasivam, P. Changes in available NPK status after eight years of continuous manuring and fertilization in Rice-Rice Cropping system. Madras Agri J.1991, 78: 204-206.
- Udayasoorian, C and Sreeramulu, U. S. Effect of continuous manuring and fertilization on soil phosphorus fractions in alfisol under rice–rice cropping system. Madras Agri J. 1991, 78 (5): 267-269.
- Udayasoorian, C., Sreeramulu, U. S and Paramasivam, P.Effect of continuous manuring and fertilization on the fractions of soil N. Madras Agri J. 1989, 76 (5): 257-261.
- Yadav, G.S., M. Datta, S. Basu, C. Debnath and Sarkar, P.K. 2013. Growth and productivity of lowland rice (*Oryza sativa*) as influenced by substitution of nitrogenous fertilizer by organic sources. Indian J Agri Sci, 2013, 83(10): 1038-1042
- Yadvinder Singh and Meelu.Integrated nutrient management in rice. Progressive Farming. May: 12, 13 and 27, 1995.

- Yadvinder Singh., Bijay Singh., Maskina, M. S and Meelu, O. P. (1988). Effect of organic manures and green manure on nitrogen and phosphorus transformations in a sandy loam soil at field capacity and under water logged conditions. Biol Ferti Soils.1988, 6: 185-189.
- Yadvinder Singh., Bijay Singh., Maskina, M. S and Meelu, O. P. Response of wetland rice to nitrogen from cattle manure and urea in a rice-wheat rotation. Tropical Agriculture.1995, 72: 91-96.