Plant Archives Volume 21, No 1, 2021 pp. 1084-1089 *e-ISSN:2581-6063 (online), ISSN:0972-5210*

Plant Archives

Journal home page: www.plantarchives.org

DOI Url: https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.143

EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON NUTRIENT USE EFFICIENCY OF MAJOR NUTRIENTS: A REVIEW

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(Date of Receiving-26-12-2020; Date of Acceptance-07-03-2021)

ABSTRACT

Nutrient use efficiency (NUE) is an important concept in the evaluation of crop production systems. With emerging nutrient deficiencies under intensive agriculture, there is a need to improve NUE. One of the approaches to enhance it is by judicious use of fertilizers (adequate rate, effective source, methods and time of application) as well as inclusion of organic manures. Organic nutrient sources are very effective but as their availability is not sufficient to meet the nutrient demand, we have to integrate both organic and inorganic sources of nutrients together in order to achieve higher NUE. Common measures of NUE include Partial Factor Productivity (PFP), Agronomic Efficiency (AE), Apparent Recovery Efficiency (RE), Physiological Efficiency (PE) and Internal Utilization Efficiency (IE). Mineral Fertilizer Equivalent (MFE) is another parameter that can be used to assess short term release of nutrients (mainly nitrogen) from organic nutrient sources.

Keywords: Nutrient use efficiency, INM, Nutrients, Mineral Fertilizer Equivalent

INTRODUCTION

Nutrient use efficiency (NUE) or fertilizer use efficiency (FUE) is an important concept in the assessment of various crop production systems. The aim of applying nutrients is to increase the overall performance of cropping systems by providing them economically optimum nourishment along with minimizing the nutrient losses from the field as well as reduction in soil pollution. Providing society with ample quantity of quality food at reasonable prices requires that cost of production remain relatively low while productivity increases to meet the anticipated demand. As a result, both productivity and NUE must be improved (Fixen *et al.,* 2014). Nutrient use efficiency of the agricultural systems can be enhanced by judicious use of fertilizers (adequate rate, effective source, methods and time of application), supply of adequate water and maintaining aeration in soil, application of suitable soil amendments in problematic soil, control of pest, diseases and weeds, planting of nutrient-efficient crop species and cultivars etc. Common measures of NUE include Partial Factor Productivity (PFP), Agronomic Efficiency (AE), Apparent Recovery Efficiency (RE), Physiological Efficiency (PE) and Internal Utilization Efficiency (IE).

Under intensive agriculture, imbalanced and indiscriminate use of plant nutrients is one of the main reasons for widespread multi-nutrient deficiencies and lower nutrient use efficiency of various nutrients. Overall efficiency of applied fertilizer have been estimated to be about or lower than 50% for N, less than 10% for P and around 40% for K (Baligar *et al.*, 2001). Repetitive use of high analysis fertilizers that are devoid of micronutrients has aggravated micronutrient deficiencies, causing considerable decline in crop productivity (Singh and Swarup, 2000). Improving NUE and water use efficiency (WUE) have been listed among most critical and challenging research issues in today's scenario (Thompson, 2012). Organic manures are the most important component of the INM system (Choudhary *et al.*, 2002; Ram, 2000). As the availability of organic sources like crop residues are not sufficient to meet the nutrient demand (Table 1 & 2), we have to integrate organic and inorganic sources of nutrients together. Sole application of plant nutrients either through chemical fertilizers, organic manures, crop residues or bio-fertilizers cannot meet the entire nutrient demand of any crop under modern intensive agriculture. Rather, all these nutrient sources need to be used in an integrated manner following a management technology which is feasible, economically viable, socially acceptable and ecologically sound (Swarup, 1998).

As it is evident that amount of crop residues generated is not sufficient, we cannot shift or depend entirely on organic practices. Therefore, adoption of site-specific integrated nutrient management practices instead of single use of either organic or inorganic sources can help in managing the declining fertilizer response and emerging nutrient deficiencies.

Mineral Fertilizer Equivalent

Mineral Fertilizer Equivalent (MFE) is another parameter that can be used to assess short term release of nutrients (mainly nitrogen) from organic nutrient sources. Nitrogen from organic amendments or nutrient sources generally has a lower availability to crops than N in mineral fertilizers, mainly depending on the C:N ratio of the amendment

Table 1: Plant nutrients addition and removal in India (Tandon, 2004)

Plant nutrients ($N+P_2O_5+K_2O$) addition and removal (MT)	Year	
	2004	**2020**
Addition of nutrients through fertilizer	18.07	29.6
Removal of nutrients by crops	28.0	37.46
Balance of nutrients	**-9.93**	**-7.86**
Total projected availability of plant nutrients from organic sources	5.05	7.75

(Flavel and Murphy, 2006). MFE gives an indication of the utilization of organic fertilizers as compared to mineral-fertilizer N and also enables comparisons of the N availability for different organic fertilizers in different years and on different soils (Thomsen, 2004). MFE can also be termed as Nitrogen Fertilizer Replacement Value (NFRV) (Hijbeek *et al.*, 2018). It can be calculated using following formula:

$$MFE\ \% = N_{of} / N_{mf} \times 100$$

Where, N_{of} - the crop N uptake in the treatment with organic-fertilizer application

N_{mf} - N uptake in the treatment with mineral-N application

Release pattern of nutrients under INM

When we apply organic manures like FYM in combination with chemical fertilizers, its nutrient releasing pattern is changed. Normally, FYM initially releases nutrients at a slower rate but on applying fertilizers like urea, the C:N ratio is lowered which results in faster mineralization of nutrients from FYM. So, greater amount of nutrients are available for uptake by the crop in the year of application and nutrient use efficiency is enhanced too.

During the year of application, plants take up the majority of the applied mineral-fertilizer N (50%–80%). In contrast, direct utilization of nutrients from organic sources in the year of application is relatively small, because of the slow-release characteristics of organically bound N and the medium and long-term N immobilization in soils (Gutser, 2005; Jensen *et al.*, 2000; Sorensen and Amato, 2002). This paper highlights the separate effects of inorganic and organic sources of nutrients and combined effect of when they are used in an integrated manner on nutrient use efficiency.

Effect of inorganic fertilizers on nutrient use efficiency

A comprehensive search of related literature revealed that application of higher fertility dose doesn't mean higher nutrient use efficiency. Banerjee *et al.,* (2015) reported that nitrogen use efficiency (NUE) was influenced greatly by the amount of N, the most efficient treatments being those which received less amount of N indicating that NUE was inversely proportional to the amount of N applied. Higher apparent N recovery in wheat was observed with 120 kg N ha^{-1} (Aulakh *et al.,* 2000). Tayefe *et al.,* (2011) observed decreasing agronomic and physiological N use efficiency in rice with increasing dose of N application. Banerjee *et al.,* (2015) reported that nitrogen use efficiency (NUE) was influenced greatly by the amount of N, the most efficient treatments being those which received less amount of N indicating that NUE was inversely proportional to the amount of N applied. Likewise, higher agronomic efficiency (kg/kg), recovery efficiency (%) and physiological efficiency (kg/kg) were attained with the application of 30 kg N/ha in barley over other N doses (Puniya *et al.*, 2015) and with 40 kg N/ha and 33.2 kg K/ha in FCV tobacco (Reddy *et al.*, 2017). Yadav *et al.*, (2015) observed significantly higher partial factor productivity, agro physiological efficiency and physiological efficiency under 9 kg/ha P application in groundnut whereas, agronomic efficiency and crop recovery efficiency were found to be significantly higher with P dose of either 27 kg/ha or 18 kg/ha. Studies have also revealed that

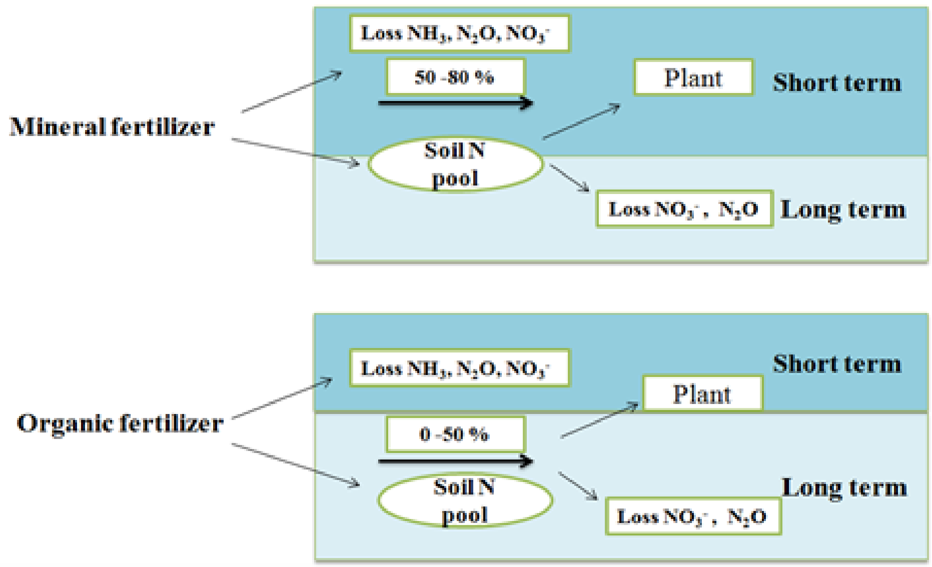

Fig. 1: Schematic overview on short and long-term effects of mineral and organic fertilizers on soil N availability (Gutser, 2005)

Table 2: Gross and surplus crop residue biomass potential in India (Hiloidhari *et al.,* 2014)

Crop Group	Gross potential (MT)	Surplus potential (MT)
Cereals	367.7	90.1
Oilseeds	48.8	13.7
Pulses	17.9	5.1
Sugarcane	110.6	55.7
Banana	41.9	10.2
Cotton	75.9	46.9
Horticulture	19.5	12.3
Other	3.9	0.4
Total	686.0*	234.5
Availability of nutrients	18.0	6.1

*If divided by total cropped area of our country, total amount of crop residues generated on per hectare basis in India is only about 4.3 t/ha.

nutrient recoveries are higher in plots treated with N + P instead of N or P alone (Aulakh and Malhi, 2004). Sharma and Tandon (1992) reported 11 % higher grain response per kg nutrient in sorghum when 120 kg nutrients/ha were distributed as 90 kg N + 30 kg P_2O_5 compared to 120 kg N/ha. Similar results were observed in wheat and rice too (Dwivedi *et al*., 2003).

Effect of organic sources on nutrient use efficiency and mineral fertilizer equivalent

Aulakh *et al.,* (2000) during a 4 years study observed higher apparent N recovery in rice with green manuring. Similarly, green manuring with millet and colza in wheat recorded higher yield, N uptake and NUE (Dayegamiye and Tran, 2001). Schroder (2007) reported lower apparent N recovery in cutgrass from organic manures as compared to chemical fertilizers. Higher yield, nutrient uptake and NUE was noticed under pressmud @5 t/ha + *Rhizobium* + PSB application in vegetable pea (Singh *et al*., 2007). Krishnakumar *et al.,* (2013) observed higher agronomic efficiency and recovery efficiency in rice under the treatment of composted coirpith + neem cake. However, they observed higher physiological efficiency and internal efficiency in the treatment of RDF (90:40:40 NPK kg ha^{-1}) during *kharif* season but these efficiencies were higher with FYM + *Azolla* in *rabi* season. Ramakrishna *et al.,* (2017) observed significantly higher agronomic efficiency and partial factor productivity in groundnut with 75% RDN applied through P enriched vermicompost using rock phosphate (3%) whereas, significantly higher physiological efficiency of N and P along with higher internal use efficiency were observed in 75% RDN applied through FYM. However, physiological efficiency of K was significantly higher with 100% RDN through FYM.

Pedersen (2001) found the higher N fertilizer replacement value in winter wheat with indigested slurry of cattle + pig applied through direct injection as compared to when applied on surface. Among all the organic sources urine recorded higher short term mineral fertilizer equivalent (MFE) followed by poultry slurry and meat/blood/bone meal. On long term basis, cattle slurry recorded higher MFE followed by sewage sludge, solid manure and bio compost (Gutser *et al.,* 2005). Schroder *et al.,* (2007) found that application of either sod injected anaerobically digested or untreated slurry recorded higher N fertilizer replacement value as compared to FYM. Jensen (2013) reported higher N, P, K and dry matter content as well as mineral fertilizer equivalent in layer manure. In another experiment, he observed higher MFE in solid manures among all the studied manures (cattle slurry, pig slurry and solid manure). Brockmann *et al.,* (2014) evaluated different application methods and noticed higher MFEs with deep injection method as compared to broadcaster and trailing shoe methods. Delin *et al.,* (2012) reported higher MFE in blood meal followed by feather meal and biogas residues. These manures also recorded comparatively higher uptake of N by cut ryegrass. Higher yield, P uptake and MFE was observed in rye grass biogas residues applied followed by wheat straw ash and oat grain ash, chicken manure and cattle slurry (Delin, 2016).

Effect of INM on nutrient use efficiency

Roul *et al.,* (2006) reported highest agronomic and recovery efficiency in rice and mustard with 100% RDN as urea:FYM:soil and 100% RDN blended with FYM, respectively. In mustard, integrated application of FYM, fertilizers and biofertilizers improved productivity and nutrient use efficiency (Chand, 2007). Significantly higher N and K uptake in cotton were noticed under treatment having RD of NPK + FYM @ 10 t/ha. However, significantly higher P uptake along with higher agronomic efficiency and partial factor productivity were achieved with 50% RD of NPK + FYM @ 10 t/ha + urea spray (Devraj *et al*., 2008). Baishya *et al.,* (2010) observed higher NPK uptake and nutrient use efficiency in potato with the application of either 100% inorganic fertilizer (120:120:60 NPK kg ha^{-1}) or with the combined application of 25 % organic N + 75 % inorganic fertilizer.

Under baby corn-rice cropping system, Nutrient use efficiency (PFP, ARE, AUE and PUE) was higher due to substitution of 30% N through organic manures, either FYM or vermicompost, and rest 70% RD of NPK applied through inorganic sources (Banik and Sharma, 2012). Similarly, Lakshmi *et al.,* (2012) recorded higher grain yield of rice with combined application of 75 % RDN + vegetable waste vermicompost @ 2.5 t/ha which was at par with 100 % pratistha organic manures and 50% RDN + 50 % pratistha organic manure. However, higher NUE was recorded with application of 50% RDN + 50 % pratistha organic manure. Singh *et al*., (2012) evaluated P and K use efficiency in rice, maize and wheat at various locations under long term fertility experiments and found that recovery efficiency of P and use efficiency of K were higher with integrated application of NPK and FYM as compared to application of chemical fertilizers alone. Higher agronomic N use efficiency and apparent N recovery in *Bt* cotton were observed with the combined application of 75% urea + 25% FYM. But, higher physiological N use efficiency and N harvest index were noticed under 50% urea + 50% FYM (Ghosh *et al.,* 2015). Singh *et al*., (2015) reported that inclusion of legumes in the cereal based cropping system resulted in higher N recovery efficiency as compared to cereal-cereal cropping systems. Results of study conducted by Mondal *et al.,* (2016) suggested that integrated use of 50% RDF + 50% RDN through mustard oil cake (MOC) or 75% RDF + 25% RDN through MOC + biofertilizer enhanced hybrid rice productivity and Partial factor productivity (PFPN). Oyeyiola (2016) observed higher phosphorus use efficiency with NPK (20:40:20 NPK kg ha^{-1}) as compared to phospho-compost treatments applied to cowpea. Girma *et al.,* (2017) observed that potato plants amended with half blended + FYM 28.8 t/ha recorded significantly higher tuber yield, P uptake, agronomic efficiency and apparent recovery of P but remained at par with the treatment of half NP + FYM @14.4 t/ha and blended fertilizer @ 277 kg/ha. Jate (2017) found that continuous application of mineral N and P fertilizers with FYM achieved higher NFUE and PFUE as well as KFUE in potato as compared to continuous application of only FYM under long term fertility experiment. In rice crop, Ramesh (2018) noticed highest agronomic efficiency, apparent N recovery, physiological and internal efficiency under 50% N through urea + 50% through pressmud vermicompost application. Similarly, split application of P_2O_5 (50:50%) along with arbuscular mycorrhiza (AM) biofertilizer in sugarcane improved agronomic phosphorus use efficiency and partial factor productivity (Patil *et al.,* 2020).

CONCLUSION

Integration of organic and inorganic plant nutrient sources has clear edge over sole application of inorganic and organic fertilizers. The physico-chemical characteristics of organic sources, particularly narrow C:N, has positive and distinct impact on nutrient use efficiency which has been integrated along with chemical fertilizers for crop production. As far as possible, the inclusion of N fixing crops in cropping schemes could be used to improve the nitrogen fertilizer use efficiency. Use of bio-fertilizers *viz*. N-fixing and nutrient-mobilizers along with INM also have potential to improve the nutrient use efficiency.

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