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Enhancing nutrients use efficiency in crops by different approaches- A review

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ABSTRACT

Nutrient use efficiency (NUE) is a very important concept in the evaluation of crop production systems. The main point of consideration is that the response of applied fertilizers and their use efficiency to get the maximum output. Nutrient use efficiency of applied fertilizers is very low due to many reasons like surface run off, leaching, volatilization, denitrification and fixation of micro nutrients in the soil due to very high pH. The highest nutrient use efficiency always occurs at the lower parts of the yield response curve, where fertilizer inputs are the lowest, but effectiveness of fertilizers in increasing crop yields and optimizing farmer profitability should not be sacrificed for the sake of efficiency alone. There must be a balance between optimal nutrient use efficiency and optimal crop productivity. Hence here is a need to understand the best soil and water management practices which helps in increasing nutrient use efficiency and yield by using less fertilizers so that the goal of sustainable agriculture can be achieved. Nutrient use efficiency can be optimized by fertilizer best management practices that apply nutrients at the right rate, time, and place and accompanied by the right agronomic practices. In this review an approach has been made to clear the concept of nutrient use efficiency and the interventions which can be used to increase the nutrient use efficiency.

Key words: Denitrification, Immobilization, Leaching, Nutrient use efficiency, Right place, Right rate, Right time, Volatilization.

N is an important nutrient for agricultural and global food safety and security and nitrogen is most important to produce food at world level for fulfillment of the demand of food. Nitrogenous fertilizers are very expensive (Cassman *et al.,* 2002). The main aim of marginal farmers is that to produce maximum production or agricultural production from the less land with the use of good efficiency of nutrients especially nitrogen fertilizer. Recovery of nitrogen fertilizer directly depends upon the condition of crop environment and management technology. It is very much costly for the marginal farmers. The losses of nitrogen fertilizer might be due to leaching, evaporation, and evapo-transpiration, ammonification and crop because of these losses the fertilizers are applied double amount to fulfill the demand of nutrients. The concept of nutrient use efficiency will help in maintaining and increasing soil fertility**.** Most of the farmers use excess amount of fertilizers i.e urea**.** Urea is inorganic fertilizer or synthetic fertilizer which is giving quick response to the crops and cereals for more production. Microorganisms (e.g. plant growth promoting) are responsible for fixation of free atmosphere nitrogen in the soil for improving nitrogen use efficiency. Application of fertilizers especially nitrogen is most important. For increasing the efficiency of fertilizers we have to adopt the exact method of fertilizer application, right rate of fertilizer and always applied at right time. Slow releasing fertilizers like prilled urea, sulphur coated urea, polymer coated urea, neem coated urea recently used to increase the nitrogen use efficiency. These are modified fertilizers which are giving the best result for improving the soil fertility by slowly releasing the nutrients in the soil, there is two type of fertilizer is present in the soil -Total Nitrogen and available nitrogen. Plant do not use total nitrogen directly but available nitrogen fertilizer will be used by the plants in more ratio. The available nitrogen fertilizer provide enhancement in the nitrogen use efficiency. Unavailability of nitrogen is the first limitation of nutrients which is showing the effect on both the total food supply and protein content in food. Godfrey *et al.,* (2010), Hawkesfor *et al.,* (2014), Raun *et al.,* (1999). Uptake and translocation of nitrogen affects basic physiological functions like the establishment of photosynthetic activity and photosynthetic capacity. (Bang *et al.,* 1997, Dreccer *et al.,* 2000), formation and continuance of sink and source capacity which are associated with biomass production and grain yield of the cereal crops (Kaizzi *et al.,* 2012). There are four major roles of nitrogen fertilizer related to production of biomass of crops and grain of cereals which have been identified.

But now a these days the use of fertilizers are totally imbalanced due to the more and more use of nitrogen fertilizer for the particular crop. This adverse effects not only shown in India but all over the world like in USA, Europe countries and in China also. Due to the over fertilization it shows the effects like water pollution, soil pollution, erosion,

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Table 1: Outlook of agronomic efficiency and Nitrogen recovery of major crops around the world.

Crop	Agronomic efficiency (Kg grain/kg N)	N Recovery
Barley	9	63
Maize	20 -50	37
Oilseed rape	17	50
Rice	10 - 30	30 - 40
Grain sorghum	5 - 12	55 - 65
Soya bean	14	50
Sunflower	22	51
Wheat	33	35 - 45

environmental pollution and some-times under-utilization in some parts of Africa and few parts of Latin America **(**Austin *et al.,* 2013) soil mining is happening, which is caused depletion of fertile soil losses. Wheat cropping is neutral but maize cropping showed negative balance (Alvarez *et al.*, 2005). In Switzerland and in United States of America use balance fertilizers (Spiess *et al.*, 2011) is perfect example of increasing nitrogen use efficiency by maize cropping. The focus must be on to reduce the effect of unbalanced fertilizers and sufficient food to secure the more population due to food security and safety with the use of proper nitrogen use of efficiency. Because nitrogen enhance the vegetative growth of crops. These primary goals are maintained by the new technology and attached same current knowledge data to control the environment bad effect and proper utilization of nitrogen fertilizer.

Model of fertilizer generator: Now a days, every fertilizer plays a vital role in agriculture sector, but in some cases the imbalanced fertilizers doing adverse effect on soil. According to agronomy department ammonium nitrate is excellent fertilizer (NH_4NO_3), due to the combination of two different nitrogen fertilizers. Earlier reported that due to the use of this fertilizer the baking fermentation quality of wheat was improved. However, its low 'N' content was compared with another generators makes the transportation, storage and application is more expensive/unit of nitrogen. For the soils having pH high the ammonium sulphate ($(NH_4)_2SO_4$) is exact fertilizer because it provide nitrogen and sulphur to the crop but the disadvantages that h very less content of nitrogen (21%) present as compare to other sources, but in another side ammonium sulphate fertilizer is very much common is many parts of the world specially in Rice cropping area. Urea and Diammonium phosphate both are very important source of 'N' and 'P'. Ammonium chloride fertilizer provides two different fertilizer i.e. nitrogen and chloride (Cl^-) for responsive crop (eg. Cereal crops) as a dual purpose but 'N' content is very less in ammonium chloride and mostly used in Japan, China, India and Southeast rice crop. Ammonium chloride and sulphate fertilizer it will increase acid in the soil and very few crops are able to tolerate acidic condition (Kaag *et al.,* 2010). Urea ($CO(NH_2)_2$) is very much important fertilizer which is used for the application of nitrogen or carbon in world wide. It is more reliable fertilizer ever for handling, storage, transport, import, export. Along with the advantage urea having disadvantage is that it is easily volatiles losses (Ni *et al.*,2015) with very phototoxic effects on sensitive crops (citrus, pine apple, apple and mango). At the stage of emergence the free NH_3 released hydrolysis toxic affect. The germination of seeds is also affected with it(Patssten *et al*., 2002).

Maintained and regulated release nitrogen fertilizer: Controlled and gradually released fertilizer like prilled urea, polymer urea and sulphur coated urea. All are very much important and successful fertilizers for the farmers. The main work of that fertilizers is slowly release of fertilizer specially nitrogen to the crops. In this way the losses of fertilizer are also reduced easily due to coated fertilizer. The volatilization process will slow down and it will get maximum fertilizer or nutrient from soil which is applied by the farmers in the form of coated fertilizer. It is also helpful to reduce the effect of leaching effects of fertilizers. (Rimski-Korsakov *et al*., 2012). This is also source of applied nitrogen fertilizer recovery (Shaviv *et al.* 2000). These fertilizers which are mentioned above releasing soluble nitrogen in the forms of NH_4 or NO_3 in the soil for many weeks and months and improving nitrogen and available nitrogen which is required to crop for complete their life cycle. Slow releasing nitrogen fertilizers are those fertilizers who are releasing nutrients by chemical and biochemical process eg. Aldehydes (Chiein *et al.* 2009, Du *et al.* 2008). Urea triazone is also used as slow release nitrogen fertilizer for longer time. As a foliar application that is good absorbed by the plants without any toxicity, if it is applied in safe or required amounts. Otherwise, leaves will be burn with the toxicity of urea fertilizer or plant will be affected by the over doses of nitrogen fertilizers.

Nitrification inhibitors: Urease inhibitors have been used commercially in few countries for their degree of success (Upadhyay *et al.,* 2012). Ambus and Jensen, 2001 used neem coated and polymer coated urea due to the use of this fertilizer the potato tube yields is increased with increase in nitrogen use efficiency from 17.8% to 58%. Delgado and Mosier (Delgado *et al.*, 1996) has been reported that urea dicyandiamide (DCD) significantly slow down the rate of N_2O emissions and loss of nitrogen to the environment.

Inoculation of micro-organisms to increase the nitrogen: Now these days so many micro-organisms are used to make fertile soil for agriculture sector with full efficiency and in future will also be modified or increased its uses for long time. The results of micro-organisms will be occurs in future very positively. For the integration (combined operation) the microorganisms are also used to reduce the fertilizer input in the soil. The pulses and green manure crops are used to fix the free atmosphere nitrogen by the nodules present in

roots, N present in unavailable form, plants can-not consume or absorb it directly. So, the micro-organisms plays important role to fix the unavailable nitrogen in available form for use **(**Bindraban *et al.,* 2015).

Rhizobium: Now, a days the rhizobium sp. are used all over the world as a micro-organisms, they fix the free atmosphere nitrogen content in soil by the leguminous crops, specially soybean and dhaincha to enhance the crop yield, economic yield and biological yield. (Callino *et al.,* 2015.) A good response is always depends upon the availability of nitrogen present in soil and inoculant bacteria which is also present in the soil at higher concentration with greater capacity to complete their work as comparison to their native population. Interaction between rhizobium spp. due to the best combination of nitrogen and phosphorous the nitrogen uptake always increased time to time (Harris *et al.,* 1985 and Fan *et al*, 2007).

Azospirilluim: Inoculation increasing the rate of yield in some selected cereal crops (Pereg *et al.,* 2016). Due to the properly fixation of free nitrogen in the soil and participated in root development by using or absorbing more amount of water and soluble minerals. By the help of azospirilluim in integrated nutrient managements the yield is increased with low input strategy or source. (El-sirafy *et al.,* 2006).

Bacillus spp.: In the wheat crop the bacillus spp. were used and they have been noticed that the yield was increased consistently with the proper efficiency of applied fertilizer at their recommend doses. (Barneix *et al.,* 2005).

Agronomic interventions: To achieve the goal and full-fillment of the food requirement, the government spending a big part of money only on fertilizers production So, here the agronomic interventions are playing vital role to reduce the requirement of fertilizers and producing more food amount from same piece of land with the helping to improve nutrient use efficiency index (Coque *et al*, 2008).

Cultivation operation: Cultivation of soil is one of the important operation to losing the soil surface for making good seed bed by deep ploughing and by shallow harrowing for making the soil properly and maintaining the soil fertility level. However, after proper mixing the soil during the cultivation operation the nutrient use efficiency is well maintained and fertility index is in equilibrium point (Bouwman *et al*, 2002).

Cover crop: A cover crop is a crop planted primarily to manage soil erosion, soil fertility, soil quality, weeds, pests, insects and diseases (Lu *et al.,* 2000). Factors choose to grow and manage specific cover crop types based on their own needs and goals influenced by the biological, environmental, social, cultural and economic factors of the food system in which they operate (Fan *et al.,* 2007). Cover crops helps in holding soil particles and prevent moisture loss and weed intensification.

Deep root system and shallow root system: Roots depth also playing vital role to maintain the soil fertility and productivity for 'NUE'. The roots depth must be changed in every season for eg. in kharif season sow shallow rooted crop and in rabi season sow deep rooted crops for proper utilization of nutrients. In the top layer of soil mostly nutrients are present and crop roots can easily take nutrients from it but due to leaching and ploughing the nutrients are also present deep in soil. Deep rooted plants are very much helpful for proper utilization of nutrients and to improving 'NUE' index easily.

Methods of applying fertilizer: Method of applying fertilizer is mostly divided in so many types like, broad casting, fertilization, foliar application, drip irrigation, sprinkling, dusting etc. but the major way is how to apply? When to apply? How much to apply? So, there is 4R Methods like-. right rate , right time (site specific nitrogen management SSNM) ,chlorophyll meter and right place.

Right rate: Most crops are location and season specific depending on cultivar management practices, climate etc. and so, it is critical that realistic yield goals are established and that nutrients are applied to meet the target yield over or under use will result in reduced nutrient use efficiency or losses in yield and crop quality. Soil testing remains one of the most powerful tools available for determining the nutrient supplying capacity of the soil (Bala subramanian *et al*, 2004).

Right time (SSNM): Greater synchronization between crop demand and nutrients supply is necessary to improve nutrients use efficiency, especially for 'N' (Aulakh and Malhi *et al.,* 2004). Split application of N during the growing season, rather than a single large application prior to planting are known to be effective in increasing N use efficiency (Cassman *et al.,* 2002). Chlorophyll meters have proven useful in season N management and leaf color charts have been highly successful in guiding split N application in rice and now maize production in Asia (Havlin *et al.,* 2004).

Chlorophyll meter: Chlorophyll meter can be used to estimate the N content of crop in general most of the 'N' found in the chloroplast of plant (Good *et al.,* 2004), it helps in measuring the leaf chlorophyll content. It has ability to self-calibrate for different soils, climate and crop varieties. It is also recommended to assess the effectiveness of late applied nitrogen in standing crops to increase grain yield and protein content (Chardon *et al.,* 2010).

Right place: Fertilizer application method has always been critical in ensuring efficiency of nutrients. Determining the right placement is as important to determine the exact application rate. Different methods of fertilizer placement available but out of these surface and subsurface placement are important (Arshdeep *et al.,* 2018). Fertilizers can be

broadcasted i.e. applied uniformly on the soil surface or applied as a band, usually 5-20 cm deep. Placement decisions depend on the crop and soil conditions which influence nutrient uptake and availability. Adequate and balanced application of fertilizer is one of the most common practice for improving the efficiency of fertilizer.

Crop rotation: Continuing cereal based crop rotations such rice wheat, intensive cultivation and complete removal of post-harvest crop residue (CR) for animal consumption and fuel or its burning have reduced the organic matter content and productivity of irrigated semi-arid subtropical soil od south Asia. Identification of effective strategies for the management of tillage and CR could foster sustainable and environmentally sound agricultural systems. By rotating the crops of different families or by adding the legume crops in cropping system increased the fertility of soil.

Fertigation: The mixing or mixture of fertilizer especially urea for nitrogen in water is giving more benefit to the plants and crops. The maximum amounts of fertilizer will be used by the fertilization. The application of fertilizer directly in liquid form very near to the root zone. Plants roots hairs are absorbing more liquid amount as comparison the roots. The loss of nitrogen fertilizer and uses in excess amount will also be reduced and will do proper utilization. The crop weed competition also reduced due to the absence of nitrogen fertilizer from the field (Arshdeep *et al.*, 2018).The efficiency of nutrients will increase by fertigation as comparison to other methods.

Leaf color chart: Simple leaf color chart (LCC) is a simple tool which is a proxy for leaf N is used as an indicator of leaf color (Abalos *et al*, 2014) Leaf color intensity, leaf N status and right time of N application, LCC is a diagnostic tools which can help farmers for making appropriate decisions regarding the need for nitrogen fertilizer applications in standing crops. Conceptually it is based on the measurement of relative's greenness of plant leaves which directly co-related with its chlorophyll content. Nitrogen is a principle component of leaf chlorophyll so; measurement over various phonological stages serves as the indirect basis for nitrogen management rice.

Residue incorporation: The portion of crops left in the field after harvesting is termed as crop residues (Braver and Shelp 2010). Crop residue plays a critical role in plant growth and development as they affect the quantity of nutrients available to crops. Plant residues are principle source as well as sink for carbon and nitrogen cycle (Burgess *et al.*, 2002). Crop residues supply nitrogen to the plants for longer duration by initially converting it into inorganic form and then mineralize it at later stage of crop when 'N' demand of crop is substantial.

Precision farming: Precision farming is an information and technology based farm input management systems which aims at the use of technologies and principles to identify, analyses and manage spatial and temporal variability associate with all aspects of agricultural productions with in fields for maximum profitability, sustainability, enhancing crop performance, protecting land resources and maintain or improve the environment quality (Abrol *et al.*, 2007).

CONCLUSION

Improving nutrient efficiency is a worthy goal and fundamental challenge facing the fertilizer industry and agriculture in general. Nutrient management is essential in modern crop production systems for improving the long term sustainability. Judicious application of fertilizer –right rate, right time, right place, and right agronomic practice targeting both high yields and nutrient efficiency will benefit farmers, society, and the environment. N management using through SSNM, chlorophyll meter and LCC gives higher grain yield and NUE as compared to blanket N recommendation. Integrated nutrient management and balance fertilization improve not only plant performance, but also NUE of production system. Use of improved scientific interventions with locally available technologies has a positive impact on NUE. Optimal time, rate, methods of application and use of specially formulated forms of fertilizer, including urease and nitrification inhibitors are also potential means for improving NUE. The opportunities are there and tools are available to accomplish the task of improving the efficiency of applied nutrients. However, we must be cautious that improvements in efficiency do not come at the expense of the farmers' economic viability or the environment.

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