MORPHO-PHYSIOLOGICAL UNDERSTANDING OF NITROGEN USE EFFICIENCY IN INDIA

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Nitrogen (N) is one of the most critical inputs that define crop productivity and yield under field conditions, and must be supplemented to meet the food production demands of an ever-increasing population. Efficient utilization of fertilizer N is essential to ensure better value for investment as well as to minimize the adverse impacts of the accumulation of reactive N species in the environment. The current average nitrogen use efficiency (NUE) in the field (Abrol, *et al.*, 1999) is approximately 33% and a substantial proportion of the remaining 67% is lost into the environment, especially in the intensively cropped areas (Abrol, Raghuram & Sachdev, 2007). The form and amount of N available to the plant can be improved by managing fertilizer-soil-water-air interactions; the innate efficiency of the plant to utilize this available N has to be tackled biologically. The biological processes involved include nitrogen uptake, translocation and assimilation, and their optimal contribution towards a desirable agricultural outcome, such as biomass growth and/or increased grain/leaf/flower/fruit/seed output, depending on the plant/crop involved. Identification of appropriate phenotypes, genotypes, molecular markers and target candidates for improvement of NUE poses a formidable challenge.

Nitrogen use efficiency

NUE can be defined as yield obtained per unit of N available in the soil (Kant, Bi and Rothstein, 2011). NUE is quantified based on apparent nitrogen recovery using physiological and agronomic parameter. Therefore, it can also be defined as physiological NUE and agronomic NUE. Physiological NUE is the efficiency with which the plant uses N from acquired available N to total plant dry matter. Agronomic NUE is the N imported from the field to the crop product/ N applied. Nitrogen use efficiency required in all environmental condition where yield is required, because it is reported that NUE is directly proportional to crop yield. For abiotic stress improvement in crops, NUE has become the second priority after drought both in the private and in the public sector. It is required to minimize N loss, maximize N uptake & reduce environmental pollution.

Needs for the improvement of NUE

Nitrogen (N) must be supplemented to meet the food production demands of an ever-increasing population. The cost of mineral nitrogen fertilizer accounts for a major portion of the total cost of production. N recovery by crops is only 30% to 35% of that applied and remaining 65% to 70% is lost into the environment through a combination of ammonia volatilization, denitrification, leaching, immobilization and runoff. Therefore, Physiologist and plant breeders need to develop cultivars that can exploit N more efficiently in order to minimize loss of N, reduce environmental pollution, decrease input cost and make more economic use of the absorbed N.

Physiological basis of NUE

There may be two components of NUE i.e. nitrogen uptake efficiency and nitrogen utilization efficiency. Young developing leaves and roots behave as sinks for inorganic N uptake, synthesis and storage of amino acid via the nitrate assimilation pathway. The amino acids are further used in synthesized in the synthesis of proteins and enzymes involved in different biochemical pathway and the photosynthetic machinery governing plant growth and architecture development.

(a) Nitrogen uptake efficiency: N uptake efficiency is the amount of absorbed N/quantity of available N. It derives biomass produced from and depends on amount of nitrogen uptake, storage and assimilation into amino acid and other nitrogenous compound during the vegetative stage.

Nitrogen uptake: Plants take up N primarily as nitrate and ammonium, with nitrate being the predominant form in most agricultural soils (Crawford and Forde, 2002). The function of several structural genes involved in N uptake and assimilation have been studied extensively in the past decade. In Arabidopsis, there are three families of nitrate transporters NRT1, NRT2, and CLC with 53 NRT1, 7 NRT2, and 7 CLC genes identified. The NRT2 are high-affinity nitrate transporters while most of the NRT1 family members characterized so far are low-affinity nitrate transporters, except NRT1.1 which is a dual-affinity nitrate transporter. NRT1.1, NRT1.2, NRT2.1, and NRT2.2 are involved primarily in nitrate uptake from the external environment (Miller *et al*., 2007; Tsay *et al*., 2007; Ho *et al*., 2009).

Amongst the CLC family members, CLCa is known to mediate nitrate accumulation in the plant vacuole (De Angeli *et al*., 2006).

Nitrogen assimilation: Nitrate, after entering the plant cell, is reduced to nitrite by nitrate reductase and further to ammonium by nitrite reductase. The ammonium derived from nitrate or from direct ammonium uptake by AMT transporters (Crawford and Forde, 2002) is further assimilated into amino acids via the glutamine synthetase (GS) and glutamate synthase (GOGAT). This pathway was termed as Glutamate synthase cycle by Rhodes, Sims and Folkes, 1980.

Nitrate is not only the predominant source of N supply to plants, but also acts as an important signal for several developmental processes. This regulation includes a rapid change in expression pattern of genes involved in carbon (C) and N metabolism and other metabolic pathways.

***(b) Nitrogen utilization efficiency*:** N utilization efficiency is the efficiency of a plant to utilized N from acquired available N in the plant for production of biomass**.** It involves N remobilization i.e. the proportion of N that is partitioned in the seed, result in final yield.

At the reproductive stage the increased supply of nitrogenous compound is necessary for optimum flowering & grain filling. At this stage both nitrogen assimilation & remobilization became crucial. Leaves and shoot acts as the source for providing N_2/amino acid (80% in the form of amino acid) to the reproductive and storage organ. Up to 80% of grain N content are derived from leaves in rice/wheat plant gave efficient method and mechanism that releases N via protease activities during leaf senescence. In the presence of protease activities stored protein reduces to amino acid. Then these reduced amino acid load in to the phloem and transported to developing grain (Figure 4). The prominent gene family which might be involved in the phloem-loading process are the amino acid permeases (AAP). In Arabidopsis, eight AAP genes are present (Liu and Bush, 2006). AAP1, AAP2, AAP6, and AAP8 have been characterized for their varied roles in amino acids transport (Okumoto *et al*., 2004; Tilsner *et al*., 2005; Schmidt *et al*., 2007; Sanders *et al*., 2009).

What happens to the rice crop when nitrogen level is low?

Plant with nitrogen deficiency often has spindly stems and their growth is stunted. In addition, their leaves turn yellowish from lack of chlorophyll and flowering is delayed. Nitrogen deficiencies first appear on the lower leaves because it is a mobile element within the plant and is often transferred from older to younger tissues when uptake is limiting. As harvested plant parts such as seeds are high in nitrogen content and require sufficient supplies for optimal growth, nitrogen deficiency is particularly damaging to crop yields. The low nitrogen availability in rice leads to decline in leaf N allocation, photosynthesis and water uptake, due to decreased demand by the plant. Similar patterns are observed in most other studies (Chapin 1980; Clarkson 1985). It has been observed that Nitrogen-limited plants have high carbohydrate status, and light-limited plants have high tissue-nitrogen concentrations (Evans 1989).

Conclusion

Nitrogen must be supplemented to meet the food production demands of an ever-increasing population. While, cost of mineral nitrogen fertilizer cover for a major portion of the total cost of cultivation. More over if we apply more amount of nitrogenous fertilizer then there will be soil pollution. Therefore, there is a need to reduce nitrogen loss, input cost and need to maximize output. So all these thing can be achieved through improving NUE. There is considerable genetic variability for NUE which provide opportunity for its genetic improvement. Moreover several candidate genes responsible for NUE have been identified in several crops like Arabidopsis, Rice and maize etc. By hybridization programme, it is possible to transfer these identified NUE related QTL to the elite genotype having good agronomic background. Incorporation of NUE trait in a genotype will increase the ultimate grain yield which will contribute to our national economy.

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