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Role of Nitrogen Fertilizer in Crop Productivity and Environmental Pollution

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Abstract Crop productivity mostly depends heavy nitrogen (N) fertilization. Nutrient use inefficiencies can cause environmental pollution through the release of greenhouse gases into the atmosphere and of soluble and particulate forms of N, P and carbon (C) in leachate and leaching into watercourses. Improving nutrient use efficiencies in agriculture calls for the development of sustainable nutrient management strategies, more efficient use of mineral fertilisers, increased recovery and recycling of waste nutrients, and, better exploitation of the substantial inorganic and organic reserves of nutrients in the soil. More energy is required to produce N fertilizer creates both higher environmental pollution and its production cost. Therefore, Nitrogen use efficiency (NUE) is more essential for agriculture development and environmental protection. NUE is a very complex process including assimilation, nitrification, translocation, nitrogen uptake and remobilization due to several environmental, genetic and management factors. Therefore, optimum nitrogen application to soil can improve the current status of soil, which increased the plant metabolism and its production. In future for breeding it is very important to increase grain yield and nitrogen utilization through modified cultivar.

Keywords Wheat, Nitrogen fertilizer, Environmental pollution, NUE

1. Introduction

Wheat (Triticum aestivum L.) is the third most commonly grown crop in the world, annually grown on over 200 million hectare [38]. It has been expected that for food production more than 50% of the human population relies on N fertilizers [12]. Nitrogen per year global demand has increased about 7.3 million tons [24]. The favourable economics production and newest varieties encouraged the extreme use of fertilizers with consequences for the atmosphere and increasing user demand for better production. The most essential for a plant grow this accessibility of water for plant and nutrients, where nitrogen is among one. Despite the financial returns, high yields, are increasingly challenged by production costs including nitrogen fertilizer and crop establishment, creating interest in unconventional systems that can decrease costs while maintaining high yields. The latest breeding programmes are working a lot on competent use of nutrient and drought resistance, as such an unfavourable growing condition leads to reduction, growth and it is basis by decline in stomatal conductance, N uptake, CO_2 uptake, and accumulation in dry soils [9].

Cereal crops contributing, more than 50% of total human calorie and a major staple food worldwide. Crop production needs to grow to continue with increasing demand, and both improved sustainability and yields are major challenges facing current agriculture. Crop production systems greatly worldwide vary due to climatic and soil fertility factors. Adequate nutrients supplied as fertilizer in areas of higher production are very important for sustainable yield. Nitrogen is a main macro-nutrient often limiting plant growth and environmental constrain. Although, higher N application has produced better yields, this is not a linear relationship, but optimum application of N increase against the cost of additional N inputs and offsetting incremental yield, which

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needs to be determined for individual cultivars N requirements [29]. Throughout crop development availability of N has essential, affecting establishment of seedling, tillering, grain filling and the whole canopy of crop. The optimization of NUE and crop production is a complex problem and will require a compound set of solutions to get suitable and meaningful results.

To address this problem, the nitrogen use efficiency in cereal grain production may be low owing to losses of N by leaching, denitrification and volatilization [11]. The challenge is to improve or maintain productivity and incomes with decreased inputs, mostly to farm more efficient and cleaned. To decrease fertilizer application, leaching losses should aim to match as much as feasible the requirements of plant N with the accessible nitrogen in soil, reducing the excess of N in soil hopeless to the plant. Therefore, the application should be the latest possible compatible with the period of improvement that still permits rapid N uptake, in order to avoiding the pollution of ecosystems reduce the N losses of unused N [40]. Both traditional plant breeding and molecular engineering could be employed to generate plants that used several processes limiting plant growth in elevated CO2 environments. Expanding research on cultivars with low fertilizer requirements and with high N absorption would be suitable to develop cultivars that absorb N more efficiently for the grain production [31]. Nitrogen use efficiency has been affected by Genetic variation in wheat production process [37]. Plant breeding to the environment is a long term proposition which a decade and even more time so its make and developed new suitable cultivar to become sure that new cultivar is performing well and suitable for consumers and farmers. Therefore, these all ideas ware undertakings to determine the quantitative physiological requirements of different levels N for some wheat cultivars to establish maximum N fertilization limits in relation to yield and grain yield response index with respect to old wheat populations and cultivars.

2. Nitrogen

Nitrogen occurs in the chlorophyll of plants and is responsible for vegetative growth. The leaves of plants that receive sufficient nitrogen have a dark, blue-green colour, which promotes photosynthesis. Photosynthesis is the process by which light energy is intercepted by plants and stored in the form of starches and sugars. This process is essential to sustain normal plant growth. Nitrogen is the main normally scarce nutrient in crop production. Therefore, most non legume cropping systems need more nitrogen inputs. Several nitrogen sources are available for use in supplying nitrogen to crops. Nitrogen is the most important mineral nutrient that plants take up from the soil in different growth stages. Nitrogen availability to crop is one of the big limiting factor in the productivity of major crops such as cereals [16]. The increase in the use of nitrogen (N) fertilizers for enhancing the agricultural production has been under consideration for the last fifty years [19]. For economic and environmental reasons, nitrogen fertilizers should be utilized more efficiently as much as possible in agriculture production. Non-agriculture neighbouring human, animal, micro-organisms and plant ecosystem has deteriorated by intensive use of fertilizer nitrogen [19]. Therefore, prevent biosphere together with an improvement of cropping system need proper used of fertilizer, have helpful in food, feed, and fiber [8]. Nitrogen-containing fertilisers that contain large quantities of ammonium and amine nitrogen have a greater acidifying effect on soil than nitrate containing fertilizers. Ammonium sulphate contains only ammonium nitrogen and sulphur that accelerates the process of soil acidification. It is used especially in irrigation areas where the pH is high and the acidifying effect therefore has a neutralising effect.

3. Mineralization

Mineralization is decomposition or oxidation of the chemical compounds in organic matter into plant-accessible forms. It is refers to the methods wherever a substance is regenerates from an organic material to an inorganic material. In N mineralization, organic N from decaying plant and animal residues (amino sugars, proteins, nucleic acids and urea) is reborn to ammonium (NH_4^+) and ammonia (NH_3^-) ions. This method is additionally referred to as ammonification. Therefore, the resulting ammonia is often regenerates to organic nitrogen where it can be used by plants and microbes. Furthermore, inorganic nitrogen applied to the soil for quick response, organic soil nitrogen mineralizes throughout the life cycle of crop and improves its nutritional status [2]. In distinction to the mineral nitrogen amount accessible from fertilizers, which is instantly obtainable to plants and should be simply quantified, the release from organic forms relies on the mineralization methods [4]. N mineralization is affected by several factors including the quality or composition of the organic substance, agricultural practices (e.g. tillage, irrigation, and cultivation), humidity, temperature, aeration, soil pH, soil structure and texture [25].

Additionally, mineralization of soil nitrogen also depends on ratio of C/N, polysaccharides content, nitrogen content, water soluble nitrogen. The light organic substance fractions of the soil, ATP content, microbial respiration and biomass are enclosed. The variety of things related with nitrogen mineralization reproduces the distinction in substrates and microbial microorganism communities getting used and sequential changes in substrate quality [5].

4. Immobilization

The nitrogen immobilization, nitrate and ammonia are picking up by microbes and are basically immobilized, or become accessible to plants depending on the C:N ratios. Once nitrogen is plentiful, each microbe and plants assimilate nitrate and ammonia. Nucleic acids, Proteins, and alternative organic nitrogen components of microbial cells and cell walls are produced with the assistance of incorporating nitrogen. Once a plant completes its growth stages and dies, completely different microbe decomposes a biomass of the plant. As a result, a little of the plant biomass nitrogen, with the type of NH_4^+, is converted back into the soil due to the process of mineralization. The remaining of the N into the plant biomass is released in soil organic substance in the form of constant component organic nitrogenous gas. Plants cannot use this constant nitrogenous gas simply and readily. Therefore, the remaining outcome of mineralization and immobilization is a reduce in the accessibility of the nitrogen added to the soil as fertilizer, and also the limited exchange of this nitrogen to a form NH_4^+ that is not focused to loss from the majority soils [35]. Return of organic resources, such as green manures, crop residues, catch crops and leguminous crop, have a distinct response in carbon (C) and nitrogen (N) return in agricultural soils. The synchronization of nitrogen availability with plant requires is essential for environmental and agronomic reasons [30].

5. Leaching Process of Nitrogen

Drained agricultural land has been known as a significant supply of pollution for each ground water and surface water [39]. In North America, Asia and Europe intensive agricultural processes have led to each superior production expense and a bigger threat from environmental hazards like as ground and surface pollution by nitrate leaching to water [39]. For many decades more stress is given on economical use of nutrients among agricultural production systems. The most important reason of this is negative effects on a ground and surface water quality that to a huge amount are created to agricultural non point-source contamination of nutrients, which are determined in several countries. Particularly in cold and wet regions this crisis is recognized, where great amounts of water penetrate through soil during periods without a crop [34]. Nitrate leaching from agricultural soil can be decreased in order to develop the use of fertilizers and to prevent Nitrate from build up in surface and ground waters [49].

6. Nitrogen Fertilization in Agriculture Crop

Today, the maintenance or restoration of soil nutrients is very important for increasing a crop yield, one most important as nitrogen. The N fertilizer in soluble is a significant to its easy uptake and assimilation during plant growth stages. Therefore, mineral fertilizers are the major source of N applied to crops [41, 48], by livestock manure [21]. There are also other sources of N like symbiotic N2 fixation by legume nodules [1]. The small amount of the atmospheric N converted to an available form to use for crop production, but it was different from place to place due soil properties [15]. Commonly, mineral fertilizers applied to the soil in different available form are urea, ammonium nitrate, ammonium sulfate and anhydrous ammonia. The crops can assimilate it easily and quickly. Together ammonia and urea are converted to nitrate at various rates depending on climate and soil conditions. Thus also have different losses types e,g volatilization, No_2 production, runoff, and leaching [27].

7. Nitrogen Uptake and Remobilization

Nutrient uptake is that the movement of nutrient to the plants. It refers to the quantity of solute, which is far away from the external medium. Nutrients generally exist in the kind of ions. They will be cations or anions. For ions to be absorbed to plant roots they need to be in contact with the basis of the root surface. Plants usually don't tend to accumulate higher amounts of NH_4^+ ions as a contrast to nitrate ions. Therefore, with the exception of some crops like as rice, toxicity symptoms commonly take place if crop plants are grown-up in NH_4^+ within the absence of nitrate [6]. The nitrogen requirement for macro-molecule synthesis within the developing kernel is met by the mobilization of formerly assimilated N available in vegetative tissues and through direct uptake and assimilation of N throughout grain filling. Mobilization of earlier assimilated N has been recommended as the major supply of N for the kernel [3]. The crop life cycle with respect to the management of N will be roughly separated into two most important phases occurring sequentially in some species or overlapping with others. Throughout the primary section, i.e. the vegetative section, young developing roots and leaves work as sink organs for the assimilation of inorganic N and also the synthesis of amino acids creating from the N pre-occupied before flowering so reduced via the nitrate assimilatory pathway [20]. These amino acids are promoting the synthesis of enzymes and proteins mostly concerned with building up plant building and also the totally different parts of the chemical process machinery.

8. Nitrogen Assimilation by Crops

For most of the crop species nitrate is the main source as like in the form of organic or inorganic [36]. The initial steps of the assimilatory pathway are the reduction of nitrate to nitrite catalyzed by nitrite reductase and nitrate reductase. It goes to the root cell membrane through high and low affinity transporters [11]. Therefore, nitrates are reduced to nitrite through the reaction catalysed by the enzyme nitrate reductase [27] followed by the reduction of nitrite to ammonia catalysed by the enzyme nitrite reductase [43]. One most important role for glutamine synthetase in photosynthetic tissue is in retaken of ammonia released during senescence processes or photo-respiration [46]. The genetic diversity of expression patterns of this gene family may also important for this process. Transgenic management for the assimilatory pathway have been positive effects [32]. Symbiotically fixed N is also an important source of ammonia readily available for several types of the crops.

9. Nitrogen Use Efficiency

Nitrogen is one of the most expensive and highly mobile nutrient having environmental impact through nitrate leaching and co_2 concentration in the atmosphere. The CO_2 concentration has been rising at the atmosphere, increasing from 280 to 379 ppm since the Industrial Revolution [45]. The rate Co_2 increases at the atmosphere may cause stomatal adjustment and therefore decreased transpiration rate of leaf. Therefore, resulting the lower supply of carbohydrate to the root during the later growth stages to take N from rhizosphere [45]. In addition, changing the capacity of root systems during growth stages are more important to take up ammonium and nitrate to promote co_2 in the atmosphere. So recently the progress of N efficient cultivars will be beneficial to environmental contamination's, farmer's input cost and will help to reduce excessive inputs of N fertilizers. NUE [33] is a nitrogen use efficiency and grain dry substances yield per unit of N available and divided it into N-utilization efficiency and N-uptake. However, a little research and knowledge is present about the accumulation of storage proteins during seed development. The economy of nitrogen in wheat is considered relationships among NUE, grain protein content, composition and N supply.

10. Management Strategies for High Nitrogen Use Efficiency

Evaluation of new agricultural technologies and practices should include evaluation of most important NUE components derived from crop physiological processes, soil, tillage methods, economic and environmental factors [23]. Grain yield, applied N, above ground plant N, grain N, post and pre-harvest root-zone soil N were applied to evaluate components of NUE. Nitrogen fertilizer using increase the cost of production for growers and may also have a ground water impact though leaching, No2 emission to the atmosphere caused by global warming and also eutrification of lakes and rivers [13, 7].

In general, nutrient use efficiency has been studied in various types of experiments, like field, greenhouse. However, according to the study are available to investigate same plant material grown in the field compared to greenhouse [17] while 40 durum and bread wheat cultivars were studied in field and greenhouse [28]. So the improvement of N-efficient cultivars will be of economic and environmental benefit to farmers and decline excessive inputs of N fertilizers. Fertilizer-N management takes into account all natural methods accountable for atmospheric system and N loss. Promising N management steps for high NUE should be considered [13] from the whole-crop scale to cellular, including, high capacity for N assimilation in the stem, leaf and canopy photosynthesis, N from leaves to grain, root traits with increasing root length density (RLD) all having a potentially high importance to increase the value of NUE in bread making wheat cultivar to feed cultivars associated with uptake and assimilation of N. However, NUE of converting plant N to grain biomass impact yield losses [47].

11. Genetic Breeding to Improve Nitrogen Use Efficiency

Nitrate reduction is very limiting for optimal biomass and grain yield production. In wheat, a gene for GS1 over expression from French bean led to enhanced the grain yield (grain weight in particular) and therefore of NUE was estimated about 20% [8]. Development of traits require to study and identify the particular genes by breeding through low and high nitrogen fertilizer condition and also may develop molecular markers for advance breeding programs. The outer layers and embryo of the grain contains about 30% of the total grain N [44]. They are enhanced insoluble proteins, globulins and alnumins, most of which are metabolic and structural functions. For access to a single gene positional cloning is another strategy to focus on the chromosomal region for controlling the interested trait [42]. Genetic modified cultivar having gluten properties and high protein content with the proper amount of fertilizer application were required to transport more N to grain and decrease its losses to the atmosphere. Climate change will significantly change N cycling processes, which will affect both terrestrial and aquatic ecosystems, as well as human health. Higher air temperatures will make difficult air quality mitigation, because larger reductions in NOx emissions will be needed to achieve the same reductions of O3 pollution under higher temperatures [50]. Such a ''climate penalty'' will impose challenges to avoid harmful impacts of O3 pollution on human health [51] and crop productivity [52].

12. Environmental Impact of Nitrogen

Nitrogen is normally odourless, tasteless, colourless and mostly diatomic non-metal gas. It is trivalent in most compounds and having five electrons in its outer shell. The challenge of nitrogen is how to optimize the use of nitrogen to sustain human life while minimizing the negative impact on the environment and human health. It is more dangerous to the health of humans and ecosystems and maybe future populations will be more stressed either due to nitrogen excesses or due to nitrogen limitations. The rapid human production of nitrogen fertilizer for higher agriculture yield and production caused environmental nitrogen concentration [22]. The main environmental problems are acidification of the water resources and soil, groundwater and surface hardpan, caused of crop injury, ozone depletion and rising greenhouse gas levels due to N_2O emission, loss of biodiversity in ecosystems [14]. It can change the composition of species due to susceptibility of certain organisms to the consequences of nitrogen compounds and also various health effects in humans and animals can cause by nitrite. In the future, we can expect fertilizer costs can increase together with the costs of all agricultural inputs and also the water resources for irrigation become increasingly inadequate so the genetic distinction in efficient use of nutrients has been shown [13]. The plant can improve through genetically to utilized N more efficiently under stress condition and optimize the targeted yield.

13. Conclusions

Many investigations have been carried out over the last two decades to identify by means of physiological, agronomic, and genetic studies to find out the best model for an NUE particular in crops or environmental benefits. Therefore, the management practices are more important for indigenous nitrogen reduction and increase occur due to nitrogen fertilizer application. Multiple ways are used to raise the productivity as well as NUE. It depends on long time agronomic and advance breeding strategies. Finally, future progress will depend on integrated works by agronomy, breeding, molecular physiology and understanding the efficient uptake of nitrogen during crop growth stages.

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