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Review Article

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Nitrogen Use Efficiency in Baby Corn - A Review

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ABSTRACT

The efficient use of Nitrogen (N) is one of the essential goals in crop management to achieve a desirable plant production (biomass). N Management is a challenging task and several methods individually or in combination are used to enhance its efficiency. However, only 33 per cent of nitrogen use efficiency (NUE) improved while developing nitrogen management tools and methods. The primary objective to improve nitrogen use efficiency via strategic management such as respective methods, soil testing, plant tissue testing, right ways of fertilizer placement and timing, vegetative indexes (leaf area index) and spectral response etc. No single method was found sufficient to stand the nitrogen loss. Some methods were found time consuming and unsynchronized with N uptake behaviour of crop, for example, plant tissue testing. Use of precision agriculture tools, such as Green Seeker, SPAD meter, and leaf color chart (LCC) were found better as compared to conventional methods such as soil testing, but these tools can only be used when the crop is up. Therefore, N management is possible only through in season N application methods. When 70% of the applied nitrogen is used by the crops within 25-30 days after sowing, for example, corn, it is required to apply major N rates through in season approach and some N at the time of sowing using soil test reports. finally concluded that using two or more methods in combination when managing the N in the crops field.

Keywords: *Nitrogen, NUE, LCC, SPAD, Green Seeker*

INTRODUCTION

Maize is the most widely researched and highly versatile crop under varied agro-climatic conditions and is broadly cultivated after rice and wheat in tropical, sub-tropical and temperate regions of the world (Singh et al., 2019). Nowadays, the diversification and value addition of maize is done by growing it for vegetable purposes which is commonly known as baby corn. Baby corn (*Zea mays* L.) is unfertilized young corn ear (de-husked baby cob) harvested after 2- 3 cm long silk emergence (Singh et al., 2010 & Singh et al., 2019). A Korean botanist, Jason H. Ahn discovered baby corn in the early 20th century and Thailand started cultivation during the early 1970s. In the last forty years, baby corn production proved enormously successful in many countries. Baby corn is a highly nutritious vegetable crop.

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In 100 g of baby corn, are found to be rich in 89.1% Moisture, 1.9 g Protein, 0.2 g Fat, 0.06 g Ash, 8.2 mg Carbohydrate, 28 mg Calcium, 86 mg Phosphorus and 11 mg Ascorbic Acid (Wang, 2009 & Thavaprakaash et al., 2005) and also rich in sugars, vitamin C, thiamine, riboflavin and folic acid with low calories and high fibre without cholesterol and by-products viz. tassel, silk, husk and green stalk are valuable cattle feed (Demjanova et al., 2009). It's popularly called the queen of cereals due to higher genetic yield potential than any other cereal counterpart (Kannan, et al., 2013 & Verma, 2013).

Baby corn can be grown year-round though the maturity of the crop varies with season i.e. rainy season (60-70 days), winter season (120-140 days) and spring season (75-90 days) thus, it is suitable for crop diversification (Singh et al., 2015). The short duration baby corn provides opportunity for its inclusion under intensive cropping systems and opens new vistas for crop diversification, value addition and economic returns (Mahajan et al., 2007). India having diverse climatic conditions requires location specific recommendations on agronomic practices (Singh & Singh, 2019).

Nitrogen (N) is a major constituent of amino acids, protein, fatty acids, nucleic acid and many enzymes and affects various physiological, morphological and biochemical processes in the plants. Thus, both vegetative and reproductive phases of growth are highly dependent on adequate N supply. Nitrogen is the most limiting in getting higher cobs production and green fodder yield. The N requirement varies with soil type, crop rotation and weather condition (Bundy et al., 2011). Baby corn requires optimum nitrogen applied at critical timings. Application of 150 kg N ha^{-1} in three equal splits, i.e. basal, 25 and 40 days after sowing improves yield (Thakur & Sharma, 1999). Baby corn needs balanced nutrition of NPK with sulphur and zinc application being high density and short duration crop. The N application usually scheduled in three splits (50% basal, 25% at knee high stage and 25% at tasseling). However, higher dose of nutrients i.e. application of 125 % RDF (187.5kg N + 93.75kg P_2O_5 + 75kg K_2O + 50kg S + 10kg Zn ha^{-1}) results in significantly higher growth and yield attributes, corn and green fodder yield with net returns of pre-Kharif baby corn (Kumar & Bohra, 2014). The farmer often applies an extra dose of N to avoid the risk of N deficiency. However, researchers suggest N management based on soil test and the use of leaf colour chart (LCC) in maize crop. The in-season N management approach may also be attempted in baby corn to optimize the N dose, possible improvement in the efficiency of applied fertilizer N with enhancing yield and profitability. Improvement in N use efficiency (NUE) is a challenging task and depends upon optimization and efficient utilization of N by coinciding with critical growth stages in baby corn.

Current scenario of NUE

To increase NUE and resolve the environmental problems, many tools and approaches have been recently developed for N management (e.g., in-season root-zone N management) (Zhao et al., 2003 & Cui et al., 2010). However, substantial, and consistent yield enhancement have been demonstrated only (Dobermann & Cassman, 2005 & Qing et al., 2012). An improved N management strategy reduces N fertilizer rates by 40 per cent, increases NUE by 16 per cent, and achieves similar maize grain yields as compared with standard farm practices (Cui et al., 2008a). Similar results were found with wheat in that improved N management did not lead to a significant yield increase but improve NUE substantially (Cui et al., 2008b). These optimal N management studies showed increased NUE in current cropping systems but attempts to manage N fertilizer application to achieve significant increases in yield and to make recommendations for future food demand have met with limited high-yielding research. The high yields by agronomists were achieved under the most favourable environmental conditions in combination with extensive nutrient inputs, regardless of the economic costs and environmental risks at selected locations (Chen et al., 2012). For example, the rate of N application in 43 high yielding maize were studies and found averaged 747 kg ha^{-1}, with more than 1000 kg ha^{-1} being applied at some sites (e.g., 1 170 kg ha^{-1} at Laizhou in 2005) (Chen et al., 2012). These application rates were substantially higher than the approximated 300 kg ha^{-1} N demand. Another example came from Shandong Province in 2007, where the maize yield was as high as 19.3 Mg ha^{-1} while more than 720 kg ha^{-1} of N fertilizer was applied, split among eight application periods. The fertilizer N surpluses in these studies related to the potential yield for the specific genotype, environment, and management practices have limited our ability to quantify N fertilizer requirements in high yielding systems and have made it more difficult to demonstrate these technologies. In addition, excessive N fertilizer inputs in these high-yielding trials have also misled farmers into believing that high N fertilizer inputs were needed to achieve higher grain yields (Wang, 2008).

Strategies for boosting NUE

Nitrogen use efficiency (NUE) is the fraction of applied N to plants that absorb and retain in the soil. The NUE is the efficiency with which nitrogen applied to soils, through natural or artificial means, is taken up by plants and not used for other purposes such as feeding anaerobic bacteria that cause denitrification or leeching via nitrogen dissolution in water (Choi, et al., 2009). N dissolution in water is often caused by over application of fertilizers, excessive soil drainage or inclined growing (Daniel et al., 2010). NUE has been widely used as a metric to relate N uptake with the quantity of N applied. One way to understand its behaviour regarding the mass of grain harvested compared to the mass of N applied. Because of variability in yield potential, N loss potential within fields, volatility in N fertilizer and corn prices over time, it is important to develop fertilization practices that can optimize the N fertilizer rates. Worldwide, nitrogen fertilizer use has increased drastically, from just over 79 million pounds in 2002 to about 99 million pounds in 2012. The NUE for world cereal production is low with estimates averaging 33 per cent of nitrogenous fertilizer recovered by the crop (Raun & Johnson 1999). The prime cause of N loss is through nitrate leaching or denitrification from excessive rainfall. The time between N application and its active absorption by the crop provides numerous opportunities for N loss from leaching, clay fixation, immobilization, denitrification, and volatilization (Scharf et al., 2002). NUE of current N management practices are low due to the poor synchrony between the N application and crop demand (Raun & Johnson 1999; Cassman et al., 2002 & Abebe & Feyisa 2017). During the first three weeks following emergence, corn uses soil mineral N at the rate of less than 0.5 kg ha^{-1} day^{-1}. However, after the first three weeks, the corn plant takes up exponentially more N until tassels, with an average of 3.7 kg ha^{-1} day^{-1} (Schroder et al., 2000) and reached the highest daily uptake of 6 kg ha^{-1} day^{-1} (J.S. Schepers, personal communication). Depending on soil and weather conditions, pre-plant N could leach below the crop rooting zone early in the season before peak N uptake (Cameron et al., 2013). Therefore, large pre-plant N applications result in high levels of available N in the soil profile before actual active plant uptake, which is at risk of loss over several weeks. The efficiency of a single pre-plant N application decreases with the rate of N fertilizer applied (Reddy & Reddy 1993). On the other hand, in-season N application results in improved NUE as compared to pre-plant N application (Olson et al., 1986). Supplying N as the crop requires could increase NUE (Keeney 1982). Another reason for low NUE is out dated N recommendations that promote over-application of N have been used to actual N requirement. Several approaches have been used to determine actual N requirement of any crop, but, due to uncertainty in its calculation methods, N efficiency is low.

Soil test approaches

Soil and plant analysis are used for N management of different crops (Cameron et al., 2013). To supply the required amount of N with consideration of spatial variability (Franzen et al., 2002). Some studies have encouraged a soil-based approach of outlining spatial variable management zones (MZ) for variable N applications and improving NUE. MZ are field areas with similar attributes in landscape and soil condition. Zones are considered homogeneous when they have similar electrical conductivity (EC), crop yield, and producer-defined areas (Flowers et al., 2005 & Kitchen et al., 2005). Such attributes tend to have similar yield potential, input-use efficiency, and environmental impact from the application of fertilizer. Most of the delineation of MZ depends upon the sources that are static and less consistent because of the temporal variation in yield potential (Jaynes & Colvin 1987 & Lambert et al., 2006). Therefore, they might not be adequate alone to account for all of the variability of N requirement in a field. A standard approach of N requirement in the main commercial crops is determined by a formula that includes yield expectations, soil test nitrate analysis before planting to 60-cm in depth, and any N credits from previous crops the efficient use of N for commercial crop production is vital to maximize economic return and minimize N losses to the environment. Regional climate, including temperature and precipitation, affect the availability of N to crops and the mineralization rate of residues and organic matter. Soils within a field also have varying characteristics (texture, pH, and organic matter content) that affect N loss through enabling leaching or denitrification in years of excessive rainfall and N mineralization rate. Estimation of crop biomass yield is sometimes used for N rate determination with C4 plants. For example, corn requires less N for a given amount of biomass compared to C3 plants such as wheat (Gastal et al., 2002). Predicting crop yield is nearly impossible due to annual variation in precipitation and pollination period temperature, particularly in dryland cultivation.

Tissue analysis for n management

The plant's sensitive use as indicators of the nutrient status of the soil. Some crops are good indicators of the overall growing conditions as they are directly linked to the weather conditions and soil management practices (Inada 1995). Usually, increased N availability in plants results in more leaf N concentrations and thus more chlorophyll (Sinclair et al., 1965) and higher photosynthetic rate (Sinclair et al., 1989). The chlorophyll content of the corn leaf as estimated by the chlorophyll meter is highly correlated with corn yield and N concentration in the leaf (Ulrich 1952). Nitrogen concentration in critical states can be used as an indicator of crop N status. Critical N is the minimum amount of N required to produce the maximum amount of growth at a particular time (Schepers et al., 1992). In corn and potatoes, the approach of critical N at the early growth stage does not provide a reliable estimate crop N status (Binford et al., 1992). and this could be due to the competition between plants (Plénet & Lemair 1999). The concentration of N decreases with increase in crop biomass, sometimes referred to as "dilution" (Plénet & Lemair 1999). The critical N dilution curve range for corn could be used up to the silage maturity (Herrmann & Taube 2004). The concept of critical N may be more practical in small-scale agricultural systems, but it is usually not practical for large-scale commercial agriculture.

Spatial variation

These spatial differences cause differences in plant N requirement, susceptibility to stress, and variation in plant productivity across a landscape. Variations in slope within a landscape can have a substantial impact on grain yield variability (Kravchenko et al., 2005). Soil depth and drainage also have a significant impact on corn grain and potato yield (Bu et al., 2017). In commercial crop production, higher N fertility levels have been observed in foot slopes and depressions due to the flow of water and soil deposition of clay and organic matter to these landscape positions. This effect is most evident in soils with upper landscape positions that are low in organic matter (Alexandra et al., 1949). Topography and slope helped to explain 30% and 85% variability in the yield of corn and soybean (Glycine max L.) cropping systems, respectively (Jiang & Thelen 2004). Although topography and soil properties offer some understanding of variability in grain yield, they are only two of many factors that contribute to variability.

Fertilizer Placement and Timing

There is a need for N application in ways that ensure a high level of N availability to the crop with high NUE. Broadcasting UAN (urea-ammonium nitrate solutions) results in lower yields than injected UAN, particularly on fields with surface residue (Fox et al., 1986 & Bandel et al., 1980). Loss of N using broadcast UAN includes volatilization of ammonia from the urea part of the solution and immobilization of N in the surface residue (Bandel et al., 1980). Therefore, fertilizer placement below the soil surface may often be more efficient. In modern crop hybrids, approximately 15% of the total N uptake and 5% of the total dry matter accumulation occurred at the V7 (seven leaf Stage) growth stage (Ewing & Runck 2015). By silking, 60% of total N uptake has taken place, and 40% of total dry matter has accumulated. Therefore, a considerable amount, around 40%, of the crop's total N uptake occurs during a 30-day period between V7 and VT (tasseling stage). There are opportunities to improve N synchronization by delaying in-season N applications until V7 without compromising with yield (Holland & Schepers 2000). Contrary to the general conclusions in (Scharf & Lory 2002). one of the sites experienced irreversible yield loss when N was applied on or after V6, which means that N availability at this site must be adequate before side-dressing to ensure that maximum yield is obtained. As the level of N deficiency increased, the grain yield response to N decreased with the more considerable delay in the side-dress N application, meaning that there was a definite interaction between the level of N deficiency and the time of N application on corn yield (Binder et al., 2000). examined N fertilizer timing in Nebraska on silty clay loam soil under double-disc tillage. The previous crop was sorghum for the first year and fallow for the second. Side-dress N at V8–V10 was one of the best ways of supplying N to corn. Soil N status affected how late the N application could be delayed without causing a yield reduction. Therefore, optimum N application time depends on the degree of N deficiency, which is related to both available soil N and the crop N demand. This was particularly true in the first year of this research, where the climate caused more severe N stress than in the second year. In Year 1, for the 0 kg N ha^{-1} N rate, N had to be applied before V6 to attain maximum yield, due to dry soils later in the season. In Year 2, with more soil moisture, the application at V16 resulted in similar yield as applications earlier in the season.

Leaf Area Index

Leaf Area Index (LAI) is the ratio of leaf surface area to ground surface area (Cowling & Field 2003). Leaf area index is a direct representation of the photosynthetic capacity of the vegetation (Whittaker & Marks 1975). For some species/communities, LAI may be directly related to vegetation productivity, but, for others, the relation of LAI to productivity depends on their variables such as light, canopy extinction coefficient, NUE, and the amount of light intercepted at the top of the canopy (Anten et al., 1995). For example, C4 plants have higher NUE, when grown in dense stands, while C4 plants produce more leaf area than C3 plants grown under the same environmental conditions (Anten et al., 1995). Several approaches have been developed to estimate LAI from remote sensing. The most used are inversions of canopy radiative transfer models (Weiss & Baret 1999) and empirical relationships between LAI and spectral vegetation indices (Wiegand et al., 1979). A shortcoming of algorithms based on vegetation indices are the difficulty in extrapolating their results to larger regions or different canopy types (Curran 1983) Vegetation index predictions are often confounded with atmospheric and background effects, canopy architecture, solar-target-sensor geometry and lack of spectrum differences when measuring moderate to high levels of LAI (Fang et al., 2003)

Optimizing Nutrient Use Efficiency

The fertilizer industry supports applying nutrients at the right rate, right time, and in the right place as a best management practice (BMP) for achieving optimum nutrient efficiency.

Right rate: Most of the crops are season specific depending on variety, management practices, climatic conditions, etc., and therefore, it is critical that realistic yield goals are established and that nutrients are applied to meet the target yield. Over- or under-application will result in reduced nutrient use efficiency or losses in yield and crop quality. Some techniques, such as laboratory testing and omission plots, are proving useful in determining the amount of fertilizer required for attaining a yield target (Witt & Doberman, 2002). In this method, N, P, and K are applied at sufficiently high rates to ensure that yield is not limited by an insufficient supply of the added nutrients. Target yield can be determined from plots with infinite NPK. One nutrient is absent from the plots to determine a nutrient-limited yield. For example, an N omission plot receives no N, but sufficient P and K fertilizer to ensure that those nutrients are not limiting yield. The difference in grain yield between a fully fertilized plot and an N omission plot is the deficit between the crop demand for N and indigenous supply of N, which must be met by fertilizers. Nutrients removed in crops are also an important thought. Unless nutrients removed in harvested grain and crop residues are replaced, soil fertility will be depleted.

Right time: Splitting of N applications 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). Tissue testing is a well-known method used to assess the N status of growing crops, but other diagnostic tools are also available. Chlorophyll meters have proven useful in fine-tuning in-season N management (Francis & Piekielek, 1999) and leaf colour charts have been highly successful in guiding split N applications in rice and now maize production in Asia (Witt et al., 2005). Precision farming technologies have introduced, and now commercialized, on-the-go N sensors that can be coupled with variable-rate fertilizer applicators to automatically correct crop N deficiencies on a site-specific basis.

Right place: The right placement is as important as determining the right application rate. Frequent placements are available, but most generally involve surface or sub-surface applications before or after planting. Prior to planting, nutrients can be broadcast applied as a band on the surface or applied as a subsurface band, usually 5 to 20 cm deep. Applied at planting, nutrients can be banded with the seed, below the seed, or below and to the side of the seed. The banded applications of nutrient tend to be higher nutrient recovery efficiency because less contact with the soil lessens the opportunity for nutrient loss due to leaching or fixation reactions. Interactions among nutrients are important because a deficiency of one restricts the uptake and use of another. Numerous studies have demonstrated that interactions between N and other nutrients, primarily P and K, impact crop yields and N efficiency. Adequate and balanced application of fertilizer nutrients is one of the most common practices for improving the efficiency of N fertilizer and is equally effective in both developing and developed countries. In a current review of experiments in China, India, and North America, balanced fertilization with N, P, and K increased first-year recoveries an average of 54% compared to recoveries of only 21% where N was applied alone (Fixen et al., 2005).

CONCLUSIONS

It is determined by this review that no one method that can be used individually, but a combined approach might help in improving NUE. Sensor-based nutrient management strategies combined with a soil testing approach at the beginning of crop planting and a split application may improve nitrogen use efficiency. Estimated LAI from the sensor (SPAD meter, Green Seeker and LCC) has shown promising results but needs more research trials for robust data collection. Maximum wavelength ranges other than the red need to be tested to confirm their applicability on high biomass crop where the red wavelength is saturated. Careful application of fertilizer best management practice, right rate, right time, right place targeting both high yields and nutrient efficiency will benefit farmers, society, and the environment.

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