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Application of nitrogen fertilizer in maize in Southern Asia: a review

Aplicación de fertilizantes nitrogenados al maíz en Asia meridional: una revisión

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Abstract

The rate, time and method of nitrogen (N) fertilizer application are strongly related to growth, development, and yield of the crop. This study principally focuses on the role of the nitrogen in growth, development, and production of the maize, emphasizing time and methods of fertilizer application and their suitable rates. The review shows that crop yield increases up to certain limit and declines if applied in an excess amount of nitrogen. Nitrogen affects various physiological and biochemical processes in plant cells that ultimately affect the growth and development of the plant. Nitrogen response by maize differs due to growth stages, environment and genotype of maize. Hybrid and improved maize varieties are more nitrogen-responsive than local varieties of maize. Proper nitrogen applications as basal doses at planting stage, split doses at critical growth stages namely knee high, and flowering stages are necessary for higher grain yield. This review serves as a useful tool to maize researchers and growers for making the right decision on nitrogen application on maize.

Keywords: Maize; nitrogen fertilization; crop growth; yield; grain nitrogen content.

Resumen

La tasa, tiempo y método de aplicación de fertilizantes nitrogenados (N) están fuertemente relacionados con el crecimiento, desarrollo y rendimiento del cultivo. Este estudio se centra principalmente en el papel del nitrógeno en el crecimiento, desarrollo y producción del maíz, enfatizando el tiempo y los métodos de aplicación de fertilizantes y sus tasas adecuadas. La investigación muestra que el rendimiento de los cultivos aumenta hasta cierto límite y disminuye si se aplica una cantidad excesiva de nitrógeno. El nitrógeno afecta varios procesos fisiológicos y bioquímicos en las células de la planta que finalmente afectan el crecimiento y desarrollo de la planta. La respuesta del nitrógeno del maíz difiere debido a las etapas de crecimiento, el medio ambiente y el genotipo del maíz. Las variedades híbridas y mejoradas de maíz son más sensibles al nitrógeno que las variedades locales de maíz. Las aplicaciones apropiadas de nitrógeno como dosis basales en la etapa de siembra, dosis divididas en las etapas críticas de crecimiento, es decir, en las etapas de crecimiento a la altura de la rodilla y de floración, son necesarias para un mayor rendimiento de grano. Esta revisión sirve como una herramienta útil para los investigadores y cultivadores de maíz para tomar la decisión correcta sobre la aplicación de nitrógeno en el maíz.

Palabras clave: Maiz; fertilización de nitrógeno; crecimiento del cultivo; rendimiento; contenido de nitrógeno en grano.

Role of nitrogen in maize

Maize (*Zea mays* L.) is the third most important crop worldwide following rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.). The maize kernel is composed of approximately 72% starch, 10% protein, 5% oil, 2% sugar, and 1% ash with the remainder being water (Perry, 1988). The use of nitrogen fertilizers results in higher biomass and protein yield and increases the concentration of protein in the plant tissue. As the protein concentration of corn grain increases, zein makes up an increasing proportion of the protein (Tsai *et al.*, 1992). Nitrogen often affects the amino acid composition of the protein, and thus the quality of nutrients. In cereals, an abundant supply of nitrogen reduces the relative contribution of lysine and threonine, thus reducing the biological value of the protein. Increased nitrogen supply often leads to kernel integrity and strength, resulting in better milling properties of the grain (Blumenthal *et al.,* 2008). Nitrogen regulates the efficiency of the use of nutrients in the plant. The nitrogen affects various physiological and biochemical processes in plant cells and, ultimately, affects growth and development (Brady, 1990). In proteins, alkaloids, nucleic acids, coenzymes, Porphyrins, nitrogen is the main ingredient. The Porphyrins are responsible for the inheritance, metabolic process and growth of plants. Porphyrins are the main component of cytochrome and chlorophyll (Jain, 2000). The protoplast of plant cells contains mainly nitrogen. It plays an essential role in the growth and proper development of the plant. The lack of nitrogen reduces the growth of the plants and lower yields.

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On the contrary, when optimum levels of nitrogen are used, higher yields are produced due to the larger leaf area and the proper growth of the plant.

In addition to its function in the creation of green tissue, nitrogen plays a very important role in the development of the ear and kernel. Studies on nitrogen translocation in the plant showed that nitrogen appears to move from other plant tissues to the ear before silking, apparently in the case of the nitrogen-intense process of kernel embryo formation (Ciampitti and Vyn, 2010).

Time and methods of nitrogen application in maize

The timing of nitrogen application affects the yield (Bhattarai *et al.*, 2004). In two split dose methods, half of the nitrogen used as the basal dose and other parts of the plant during the Knee high stage are inevitable. Of course, there is a need for half of the total nitrogen remaining at knee high and tasseling stage as equal split doses are necessary. Crop productivity and the availability of nitrogen are unfavorable when used very late in the growing season. When a small amount of nitrogen is used in the initial stages of growth, the rate of nitrogen absorption is greatly reduced by the plant. During central of vegetative growth, maize plant starts to uptake Nitrogen at a faster rate and continues at silking stage to be at peak point (Hanway, 1963). Use of nitrogen in early plant growth improves yield and improves vegetative growth and development, and when is given in later stages of plant growth, late maturity and maturation cannot adequately promote the final yield. Although the level of nitrogen in the grain increases, it is used in later growth stages (Sankaran and Subbiah Mudaliar, 1997).

Therefore, an excellent method of fulfilling a higher demand for Nitrogen could be its application during tasseling and silking stages. Maximum grain and better biomass yield observed after the application of Nitrogen @ 80 kg/ha in two split doses ; half part applied at sowing as basal and remaining half during knee-high stage as side dress respectively. Nurudeen *et al.* (2015) found that the application of nitrogen fertilizer @ 80 kg N/ha gave higher benefit cost ratio (1.5). Bhattarai *et al.* (2004) found that during the sowing, earthing up and silking stages, the nitrogen applied at 3 equal divided doses to 60 kg/ha, maximized the yield of corn grain.

In comparison to traditional broadcast fertilization, fertilization in rows or fertilization in rows combined partly with top dressing increased the values of a percentage of fertilizer nitrogen in the total nitrogen uptake as well as the agricultural and physiological effectiveness of the nitrogen use (Szulc *et al.*, 2016).

Effect of nitrogen on growth of maize

Maize is a plant that requires a high quantity of nutrients due to its enormous nutrient utilizing capacity. A higher volume of nitrogen is required for higher yield. Nitrogen is required in a more significant amount than other nutrients. Low yields occur when less nitrogen is used during the stages of tasseling and silking stages, but factors such as nutrient in soil, relief, variety and the expected value of maize yield influence the need. The general nutritional recommendation for corn crops is 120: 60: 40 kg/ha, N, P, and K respectively (Singh and Singh, 2002). The rate of application of nitrogen affects the yield of corn (Abebe and Feyisa, 2017). The excessive use of nitrogen in the plants causes continued growth and results in late maturation period. Similarly, lodging occurs due to weak stems with reduced cell walls (produced by overuse of nitrogen). Resistance to pests and diseases of the plants also decreased due to high nitrogen consumption. The capacity of the crop to absorb and use nutrients in the soil depends on the presence of nitrogen in the plants. Therefore, maize yield is reduced due to lack and excess of nitrogen, so the use of nitrogen fertilizers plays an important role in better yields (Goydani and Singh, 1968). The efficient use of nitrogen varies from 150 to 200 kg/ha (Mkhabela and Pali-Shikhulu, 2001).

Diallo *et al.* (1997) found that leaf senescence got increased due to smaller leaf area and less photosynthesis due to nitrogen deficiency. When nitrogen consumption increased from 0 to 150 kg/ha, the height of the plant extended between 164 and 209 cm (Sharma, 1973). The leaf area index was also significantly higher in all phases of plant growth when nitrogen was used in the range of 60 to 180 kg/ha. Thakur *et al.* (1998) found that increment of amount of Nitrogen applied results more leaf number and thicker stem. Leaf area and leaf number significantly increased by both rate and application of Nitrogen (Hati and Panda, 1970).

Nitrogen applied to range from 0 to 150 kg/ha significantly increased dry matter at every crop growth stages (Terman and Allen, 1974). Shrestha (2015) found early tasseling and silking stages in maize occurred as result of higher nitrogen application at 200kg N/ha. Rai (1961) reported that application of nitrogen as well as increase in its rate induced earliness both in tasseling and silking stages. Yadav (1990) also found earlier silking occurred due to a higher percentage of Nitrogen applied.

Effect of nitrogen on yield and yield components of maize

Shrestha (2015) found that the application of higher nitrogen dose (200 kg N/ha) gave the highest number of cobs/plant (1.09), cob length (15.90 cm), cob diameter (5.10), number of grains/grain row (32.54,the number of grain rows/cob (14.11), number of grains/cob (459.9) and the greatest test weight (318.2g) and shelling recovery (72.14%). Also, thicker cob diameter was observed (Hati and Panda, 1970). Singh (1973) found that a higher level of Nitrogen markedly increased grain number per cob and grain weight per cob. Application of 210 kg N/ha maximize ear length to 15.64 cm (Pokhrel *et al.*, 2009). Likewise, Nitrogen applied to range 60 to 240 kg/ha effectively improved stover yield (Krishnamoorthy *et al.*, 1974). Yadav (1990) found that in comparison to 0 and 30 kg N/ha applied, grain:stover ratio for 90 and 60 kg N/ha were significantly improved. Whereas, grain yield for 80, 120 and 160 kg N/ha noted to be increased by 114.59%, 160.8%, and 58.3% respectively compared to 0 kg N/ha used (Verma and Singh 1976).

Deficiency of Nitrogen showed an increased number of barren crop plants (Singh, 1988). Kamprath *et al.* (1982) noted that barrenness in plant increased when Nitrogen applied to range above 168 to 280 kg/ha but significantly reduced when used between 56 to 168 kg/ha. A higher level of Nitrogen applied enhanced test grain weight (Gokmen *et al*., 2001; Wajid *et al*., 2007). Gungula *et al.* (2007) and Dawadi and Sah (2012) found a higher application rate of Nitrogen effectively increased kernel number per ear and kernel rows number per cob. A higher level of Nitrogen (180 kg N/ha) improved seed yield to 2.85 t/ha of inbred (NML-1) maize (Adhikary and Adhikary, 2013).

Grain nitrogen uptake

The presence of nitrogen (N) in maize and genotype are two main factors affecting grain yield (GY) and grain nitrogen content (GNC). The high GY is also based on longevity of leaves, which depends on the balance between post-silking N uptake and remobilization of vegetative N. Due to complex interactions between N uptake, N-remobilization, dry matter production (DM), GY and GNC, selection of high GNC hybrids as a single target often led to low GY (Uribelarrea *et al.,* 2007).

Nitrogen uptake by the maize plant increases its concentration in both the plant or in the grain due to the higher total dry matter content. The nitrogen applied from 0 to 150 kg/ha showed a proportional enhancement in grain yield and nitrogen concentration in the various parts of the plant (Ram and Thakur, 1966). Also, Nitrogen used up to 160 kg/ha was useful for the nitrogen concentration in the grain, higher nitrogen levels increased both nitrogen absorption and nitrogen content in maize (Ahlawat *et al*., 1981). In the same way Pokhrel *et al.* (2009) found that more nitrogen applied produces a larger nitrogen intake per grain due to higher dry matter yield. Dry matter yield positively correlated with the absorption of nitrogen by maize plant (Lian, 1991).

Factors affecting nitrogen requirement in maize

The rate of nitrogen fertilizer needed to be supplied to a maize monocrop is influenced by the soil nitrogen content (Carefoot *et al*., 1989), N source (Bache and Heathcoat, 1969; Jones, 1976), soil reaction (Riley and Barber, 1971; Jones, 1976), rainfall (Dennett, 1984), maize maturity period (Mackay and Barber, 1986) and yield level desired (Arnon, 1975). Martins *et al.* (2008) reported that higher soil nitrogen resulted in higher nitrogen absorption of plants, influencing the physiological, biochemical and agronomic traits.

Improved maize cultivars could be more efficient in using nitrogen fertilizer than the local varieties (Sallah and Twumasi-Afriyie, 1999). Hybrid maize is a heavy feeder and more responsive to nutrients (Sarkar et al., 2000). Muza *et al.* (2004) found that the commercial maize hybrids require high nitrogen levels and fertile soils and hybrids are more responsive to nitrogen fertilizer.

Plant population ranging between 69,000 and 81,000 plants/ha, showed a significantly higher uptake of nitrogen than the 57,000 plant population/ha observed during 12 leaf and tasseling stages (AL-Kaisi and Yin, 2003).

Adhikari *et al.* (2016) and Sherchan *et al.* (2004) also reported that response of nitrogen and its application time to maize differs due to genetic characters, growing season (winter, spring, and summer), maturity period (early and full season), and growing domain (mountain/hill and Terai).

Losses of N takes place due to several reasons like leaching as well as volatilization from most of the soils, only one nitrogen management strategy may not be reliable, because the loss occurs in various ways. If nitrogen supplied is under the demand of the plants, the efficiency of use of nitrogen increases (Keeney, 1982).

Conclusion

The nitrogen is essential for physiological and biochemical processes that ultimately affects growth and development. The application of nitrogen up to 200 kg N/ha increased the growth traits, yield and yield attributing traits. The nitrogen uptake in grain increases with application of increased level of nitrogen up to 150 kg N/ha applied in soil. The amount of nitrogen fertilizer varies with soil and environmental condition as well as genetic architecture of plants. This study suggests that recommended nitrogen application as basal dose at planting stage, split doses at critical growth stages namely knee high, and flowering stages should be applied for enhancing maize production.

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