Maize Journal (October 2022) 11(2): 83-87
REVIEW PAPER

A review of nitrogen management strategies and their implications on maize (*Zea mays* L.) performance

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Abstract: Maize (*Zea mays* L.) is one of the most versatile crops grown throughout the tropical as well as temperate regions of the world. These days, high external inputs required for high-yield goals largely depend on artificial sources and methods, among which nitrogen (N) is a source of worry worldwide. Crops need N for active growth and photosynthetic activity throughout the entire growth cycle. In Indian soils, N deficiency is a widespread problem, and correct management is crucial from an economic and environmental standpoint. Effective use depends on timing, technique, and optimal N application that is in tune with crop needs. Since maize has the largest yield potential of all the grains, it drastically depletes soils of N and water. Among other methods, maize's response to high N fertilisation levels is a way to determine maximal productivity. Not only is crop productivity affected by N supply, but also crop quality. Employing inorganic fertiliser can boost crop output, but protecting the environment for future generations is burdensome, especially given the ongoing rise in the global population. It is possible to achieve sustainable agricultural yield by using fertilisers, both organic and inorganic, strategically.

Keywords: Nitrogen, Organic, Efficiency, Sustainable, Crop productivity

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Received: 10 July 2022/ Accepted: 21 September 2022

Introduction

Globally, maize is cultivated on 201.98 million ha in more than 150 countries, having wide variations in soil, climate, biodiversity and management practices. Maize provides a staple diet for more than 900 million people in developing nations. It served as a fuel source as well as a source of raw materials for the manufacturing of food sweeteners, alcoholic drinks, protein, oil, and starch. Because of its greater adaptability, the crop is flourishing in a variety of global climatic conditions (Hartkamp, 2001; Amanullah *et al.*, 2007). The total production of maize in the world is 1162.35 million tonnes, with a yield of 5.75 tonnes /ha. India occupied 4th place in area and 7th in production of maize among the cereal crops. It ranks 3rd among the cereals in India after wheat and rice. It is cultivated on 9.86 million ha with a production of 31.51 million tonnes and a productivity of 3.19 tonnes/ha under a wide range of agro-ecological situations (Anonymous, 2022). Maize is a nutrient-exhaustive crop that demands high nutrition for its growth and development. The productivity of the crop depends on the nutrient management. Nitrogen and phosphorus are more important for the development of maize than other essential elements. A sufficient amount of essential nutrients must be supplied to ensure a good yield and maintain soil fertility. It has been demonstrated that increasing maize yield and soil fertility requires balanced nutrient application through the incorporation of organic and inorganic fertilisers (Almaz *et al.*, 2017; Manjunath *et al.*, 2021). Efficient use of N is important for maize production as it increases the yield and maximizes economic return and minimizes NO_3 leaching. Nitrogen is an essential nutrient for crop production. It is part of every cell, a component of amino acids and nucleic acids, and especially, it is a major constituent of chlorophyll. When a plant is nitrogen deficient, it normally shows symptoms like chlorosis or yellowing, mainly in older leaves since it is a mobile nutrient in the plant. In corn, if the deficiency is severe, it is common to observe an inverted V-shaped necrosis in the lower leaves starting at the leaf tip. Several organic and inorganic nitrogen sources can be used to supply the nitrogen required for optimum crop growth.

Adequate nitrogen not only affects maize yield but also grain quality. The application of nitrogen at low rates reduced the grain yield of maize by 43-74 per cent and the number of grains per plant up to 33-65 per cent (D'Andrea *et al.*, 2006). With the increase in nitrogen dose, yield and protein concentration in maize seed increased. The yield of maize grain produced per unit of nitrogenous fertilizer applied depends upon the uptake from fertilizer and soil N and its utilization. Nitrogen is absorbed by maize plants throughout their growth period. The plant has the greatest need for nutrients during the tasseling, silking, and grain formation stages. However, a relatively high nutrient concentration is necessary for maximum growth during the vegetative growth period. Application of nitrogen at the initial stage of the crop enhances the growth rate of leaf and root and ultimately it increases the yield of the crop. Nitrogen is important for plant metabolism as it participates in proteins and chlorophyll biosynthesis. The goal of this review study was to understand the effects of various nitrogen management practices on maize growth, yield, quality, and nutrient uptake.

Materials and methods

Identification, Screening, and selection processes were followed in this systematic review. Based on identification and screening, Literature on various aspects of nitrogen management in maize were gathered. During the screening process, more than 20 documents were identified. Only those who focused on nitrogen management in maize crop with full text available in English were kept for the selection process. The main objectives and criteria in nitrogen application methods in maize crop are:-

- *Foliar application:* Either water-soluble solid fertilizers or liquid fertilizers are mixed with water in the right proportion and sprayed on the foliage of plants for direct absorption of nutrients.
- *Fertigation:* Fertigation is the technique of supplying dissolved fertiliser to crops through an irrigation system.
- *Broadcasting:* It refers to spreading fertilizers uniformly all over the field.
- *Band placement:* It refers to the placement of fertilizers in the soil at a specific place with or without reference to the position of the seed.

Results and discussion

Effect of N management on growth parameters

Thakur *et al.* (2022) carried out research at Indore (Madhya Pradesh) and reported that [40 kg N as basal followed by (fb) 2 splits of 40 kg N and 38.8 kg at 30 and 52 days after sowing (DAS) and 1% N foliar spray at 40 DAS was found to be promising under rainfed conditions. According to Begam *et al.* (2018), plant height increased when N levels rose from 75 to 150 kg ha^{-1}. The harvest index, LAI and dry matter accumulation were considerably higher with 125 kg of N per hectare and lower at 75 kg N application. Regarding the timing of the application of N, treatment S1(½ as basal + ½ at 25 DAS) initially showed higher plant height, while treatment S3(½ as basal + ¼ at 25 DAS + ¼ at 45 DAS) ultimately produced better results. According to Verma (2011), the application of 150 kg of N_2O per hectare was much more effective for maize growth and grain yield than applications of 100 kg and 50 kg of N_2O per hectare in both years. And among organic sources, FYM @ 7.5 t/ha was proven to be the best treatment. Khadtare *et al.* (2006) conducted research at the college farm of the Anand Agricultural University in Anand (Gujarat) during the rabi season of 2005-2006. They reported that significantly higher values were obtained for cob girth, cob length, and green cob weight in treatment having recommended dose of fertiliser (RDF) (150-50-0 kg N-P-K/ha), followed by 75% recommended dose of nitrogen

(RDN) + 25% N through vermicompost (VC) made from *Parthenium hysterophorus* and 75% RDN + 25 %N through VC prepared from *Amaranthus spinosus*. According to Sharifi *et al.* (2021) observed that potassium fertilization effects on growth of hybrid maize under semi-arid conditions of Kandahar province of Afghanistan.

The application of 100 kg N/ha and 7.5 t FYM/ha significantly affected the plants' height, leaf area index, and length of time until maturity and silking (Verma *et al.*, 2012). In the spring of 2007, research was conducted at the University of Agriculture, Faisalabad's Agronomic Research Area. The treatment of urea and poultry manure had a substantial impact on all of the measured parameters, including plant height, cob length, number of grains per cob, grain weight per cob, 1000-grain weight, grain yield, biological yield, and harvest index. While the application of 50% N from urea + 50% N from poultry manure resulted in the observation of the highest grain yield (5.6 t ha^{-1}) (Cheema *et al.*, 2010). According to Meena *et al.* (2021) reported that growth and physiological indices changes in maize with differential residue and nitrogen management under conservation agriculture practices.

Effects of N management on yield parameters

In an experiment conducted by Singh *et al.* (2017), it was found that applying 300 kg N ha^{-1} was more profitable than applying nitrogen at other levels. With 300 kg N ha^{-1}, the highest values of cobs per plot (136), cob length (19.2 cm), grains per row (34.2), grain row/cobs (20.0), cobs girth (13.2 cm), test weight (244.7 g), grain yield (9.5 t ha^{-1}), and stover yield (10.1 t ha^{-1}) were measured. The maximum values of cobs/plot (129.0), cobs length (19.8 cm), grains/row (30.7), grains row/cobs (18.8), cob girth (12.2), test weight (238.7g), grain yield (8.4 t ha^{-1}), and stover yield (9.5 t ha^{-1}) were all recorded with five nitrogen splits (Table 1). The maize variety JM 218 and nitrogen scheduling, according to Thakur *et al.* (2022), were found to be promising because they generated higher grain yields (6139 kg/ha and 6197 kg/ha), stover yields (11,107 kg/ha and 11,207 kg/ha), and cob attributes (cob length, number of grain rows, and test weight). A greater cob/plant, grain/cob, and seed index were also reached with 125 kg N ha^{-1} in addition to a better grain yield (5.99 t ha^{-1}). Begam *et al.* (2018) found that the combination of N applied three times (12 as a base application + 14 at 25 DAS + 14 at 45 DAS) and applied subsequently resulted in a greater grain yield of 5.63 t ha^{-1}. Meena

In Rajasthan, Golada *et al.* (2013) found that the maize yield attributes, yields, and net returns were significantly enhanced by increasing N levels up to 90 kg ha^{-1}. Green cob production increased significantly when N applications of 90 and 120 kg N ha^{-1} were given, increasing over 60 kg N ha^{-1}. The findings showed that applying nitrogen up to 90 kg ha^{-1} considerably improved the production of green cobs and baby corn by 20.5 and 23.6 per cent, respectively as compared to applying 60 kg ha^{-1}. Srivastava *et al.* (2017) reported that maximum total dry matter, grain yield (t/ha), kernel number/cob and cob number/ m^2 was found with early sowing date and nitrogen level at 125 kg/ha. According to Neupane *et*

Table 1. Effect of nitrogen and its scheduling on yield and economics of *rabi* maize (Mean of 2 years)

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Total profit (Rs X 10^3)	Net profit (Rs X 10^3)	Benefit cost ratio
Nitrogen (kg ha^{-1})					
150	6.9	8.1	104.4	69.6	2.9
200	7.9	8.7	118.7	83.2	3.3
250	8.8	9.3	131.8	95.5	3.6
300	9.5	10.1	143.2	106.3	3.9
CD (P=0.05)	0.5	0.5	14.5	8.5	0.1
Nitrogen scheduling					
3 Split	6.7	7.9	101.2	65.3	2.8
4 Split	7.4	8.5	111.3	75.5	3.1
5 Split	8.4	9.5	127.3	91.4	3.5
CD (P=0.05)	0.4	0.5	13.4	7.5	0.1

Source: Singh *et al*. (2017)

al. (2017), genotype HM-4 generated 4.6 and 4.1 per cent greater maize weight and cobs than HQPM-1. In comparison to 3 splits (50% B), in 4 splits with a higher basal (B) dose, RDN increased cob and maize output by 4.8 and 5.1 per cent, respectively. According to the results, RDN should be used to grow HM-4 at a rate of 50 per cent as B, 25 per cent at knee height, 20 per cent at tassel emergence, and 5 per cent foliar spray after first picking as urea solution (3%) to increase yield. According to research by Gomaa *et al.* (2017), the foliar application of nano and the soil application of mineral fertilisation (K and P) had a significant impact on biological, grain, and straw yields in both growth seasons. The highest values of biological, grain, and straw yields (18.76 and 17.93 tons/ha), (8.68 and 8.35 tons/ha), and (10.08 and 9.58 tons/ha), respectively, were obtained with the application of mineral fertiliser in the soil + foliar application of nano fertiliser followed by foliar nano-fertilization treatment. Sharma *et al.* (2021) also reported that maize yield was increased by 10-25% under new stabilized urea fertilizer (AGROTAIN incorporated urea) in maize-wheat system compared to control method.

Effect of N management on economics

According to Kalhapure *et al*. (2013), using 25% RDF plus biofertilizers (Azotobacter + PSB) + green manuring with sunhemp + compost resulted in the highest gross return (Rs 95.9x10^3/ha), net return (Rs 54.2x10^3/ha), and B:C ratio (1.30). However, Singh *et al*. (2017) reported that maximum net returns and benefit-cost ratio were achieved with 300 kg N ha^{-1} and 5 splits of nitrogen and Golada *et al.* (2013) also reported that increasing nitrogen levels up to 90 kg ha^{-1} markably improved the net returns and benefit cost ratio of maize crops. The pooled data of two years experiment inferred that nitrogen level of 125 kg ha^{-1} and applied in three growth stages (½ as basal + ¼ at 25 DAS + ¼ at 45 DAS) in maize can be used for yield increase and higher profit as per the reportings of Begam *et al.* (2018).

Effect of N management on nutrient content, uptake and quality parameters

Neupane *et al*. (2017) reported that the combined approach resulted in higher N uptake and protein content. According to the results, 50 per cent RDN should be supplied as the basal dose. The rest of 25 per cent at knee height, 20 per cent at tassel emergence, and 5 per cent as a foliar spray after first picking as urea solution (3%) to increase nitrogen and protein content in corn and fodder (Manikandan and Subramanian, 2016).

During the rabi season of the year 2005-2006, a field experiment was carried out on the medium calcareous soil of the Instructional Farm at the Junagadh Agricultural University in Junagadh (Gujarat) to examine how rabi maize (*Zea mays* L.) responded to vermicompost and nitrogen levels. The application of 120 kg N/ha + 1.5 t vermicompost/ha produced noticeably better nutrient content and absorption as compared to the application of 80 kg N/ha + 1.5 t vermicompost/ha and control treatments (Meena *et al.*, 2007).

In a field experiment conducted by Shinde *et al.* (2014) in Parbhani (Maharastra) during the rabi seasons of 2004-2005 and 2005-2006, it was discovered that the application of 100% RDF (120-60-40 kg N-P-K/ha) + 10 t FYM/ha led to the highest maize protein content. According to Manikandan and Subramanian (2016), treatment with nano-zeourea consistently resulted in higher maize growth, yield, quality, and nutrient uptake than treatment with traditional urea (Manikandan and Subramanian, 2016).

Conclusion

Results showed that integrated nitrogen management techniques on maize crops provide multiple benefits for increasing soil fertility and agricultural yield in environmentally friendly methods. The data presented in this review paper allow for the conclusion that varied nitrogen treatment rates and timing considerably affect growth metrics *i.e.*, plant height, aerial dry matter accumulation, leaf area index (LAI) and grain yield.

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