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Effect of nitrogen levels on growth parameters, yield parameters, yield, quality and economics of maize: A review

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Abstract
Nitrogen plays a prominent role in deciding the overall physiological process and biochemical reactions contributing to higher productivity and quality of maize which is a high nutrient exhaustive crop. Optimal dose of nitrogen application is necessary to obtain maximum yield and higher net returns from maize cultivation. The findings of different research scientists and eminent investigators with regard to growth parameters, yield parameters, yield and quality of maize will aid in understanding effect of nitrogen levels on growth parameters, yield parameters, yield, quality and economics of maize. Application of nitrogen at 150 to 200 kg ha^{-1} is found to be significant in improving the growth, yield (grain yield, Stover yield) and quality (protein content, crude protein and fibre) of maize with maximum net returns for maize cultivators.

Keywords: Maize, nitrogen, optimum dose, yield, quality, net returns

Introduction
Maize, queen of cereals ranks third with regard to human food and animal feed after rice and wheat in India. Productivity of maize in India (2583 kg ha^{-1}) is lower compared with other countries (5160 kg ha^{-1}) due to improper dose of nutrient supplement especially nitrogen which determines yield and quality. Nitrogen is the vital nutrient that is essential for protein synthesis, cell multiplication and differentiation. It aids in formation of chlorophyll pigment thereby enhancing the photosynthesis contributing significant role in growth and reproductive phases of crop. The biochemical process in plants is mainly influenced by nitrogen status leading to alteration in physiological process. The nitrogen contributes to 1-4% of dry matter and also enhances the translocation of reserve photoassimilates as well as uptake of other essential nutrients. Excess application of nitrogen or deficit declines productivity of maize hence optimal supplement is in need of the present hour as nitrogen is proned to losses. Yield components of maize and yield were mainly determined by the nitrogen level application which is the key nutrient for all biochemical reaction enhancing source to sink capacity and quality (Mahammed and Shirdon 2013) [42]. Yield reduction occurs due to low nitrogen status as a result from less assimilate partitioning from source to sink which is reduced by small leaf area, low light interception and photosynthetic process Glamoclija *et al.*, (2011) [20]. Crop production is enhanced by supplying nitrogen at higher dose in appropriate time which plays prominent role in deciding overall productivity by promoting all yield parameters Khaliq *et al.*, (2009) [34]. (Gheysari *et al.*, 2009; Hammad *et al.*, 2012) [19, 23] stated that increasing the level of application of nitrogen enhances productivity of crop is an effective measure to avoid yield penalty. Singh and Nepalia (2009) [70] stated that nitrogen boosts photosynthetic process that aids in translocation of produced assimilates into the different sink parts such as number of cobs per plant, cob length, cob diameter, number of grains per cob and seed index in maize. Kumar *et al.* (2005) [38] stated that plant height, number of leaves per plant, leaf area index, dry matter production, fodder yield and nutrient uptake were increased with nitrogen application at higher rate that determines overall productivity of maize.

Effect of nitrogen levels on the growth parameters of maize
Lang *et al.*, (1956) [40] documented that application of nitrogen at higher doses significantly increased plant height of corn especially in the early stages. Thakur *et al.*, (1997) [73] reported that significant increase in plant height, number of leaves per plant and dry matter production

with 200 kg ha^{-1} of nitrogen application than lower levels in early composite varieties of baby corn. Shivay and Singh (2000) [64] divulged that increasing nitrogen dose up to 120 kg ha^{-1} gave significant increase in plant height, leaf area per plant, leaf number and dry matter with no application of nitrogen. *Shivay et al.,* (2000) [64] found that application of nitrogen at higher levels increased plant height of maize from his research trial. Similar results were reported growth parameters of plants were influenced by nitrogen status and application Robson and Deacon (1978) [62]. Mehrabadi and Mohassel (2000) [48] reported that growth parameters were significantly higher with increasing levels of nitrogen. Mehmood *et al*. (2001) [44] divulged that higher levels of nitrogen increased plant height of maize plant than control treatment. Ayub *et al.* (2003) [5] reported that higher levels of nitrogen application gave significant increase in growth parameters *viz*., plant height, stem diameter, dry matter production. Keskin *et al.,* (2005) [33] documented higher plant height in forage maize with 200 kg ha^{-1} of nitrogen application. Maurya *et al.,* (2005) [45] disclosed that plant height, number of functional leaves, leaf area index and dry matter production were higher with 150 kg ha^{-1} of nitrogen application than lower levels and control. Dry matter content of maize increases with increasing levels of nitrogen upto 100 kg ha^{-1} of application from his study on different nitrogen levels on maize Adiloglu and Saglam (2005) [1]. Bindhani *et al.,* (2005) [9] found that application of nitrogen at 120 kg ha^{-1} gave significantly higher plant height, leaf area index and dry matter production with 120 kg ha^{-1} than lower levels in baby corn. Choudhary *et al.,* (2006) [58] documented leaf area and dry matter production were statistically significant with 120 kg ha^{-1} of nitrogen application than lower levels. Taller plants, leaf area, dry matter production and stem diameter was higher with application of 80 kg ha^{-1} of nitrogen application than control and lower levels and control in forage maize from his experiment Hani *et al.,* (2006) [24]. Higher plant height, number of leaves per plant and earliness in tasseling and silking was found with application of 200 kg ha^{-1} of nitrogen than control and lower levels in maize Bakht *et al.,* (2006) [6]. Chlorophyll content and leaf area index were significantly higher with 180 kg ha^{-1} of nitrogen application over no application in summer maize Xie *et al.,* (2006) [77] and (Ram *et al.,* 2006) [56]. Plant height was higher with application of nitrogen with increasing rate from 180-300 kg ha^{-1} in maize hybrid. Dry weight of leaves and plant height were more at 140 kg ha^{-1} than lower levels in maize Siam *et al.,* (2008) [67]. Application of nitrogen at 150 kg ha^{-1} surmised that significantly higher in plant height, leaf number than lower levels and increasing rates were statistically on par in sweet corn Kunjir *et al.,* (2009) [39]. Das confirmed that application of 120 kg N ha^{-1} increases plant height, stem girth and number of leaves from his research trial in maize. Singh (2010) [68] documented maximum number of leaves per plant with application of 175 kg ha^{-1} than lower levels. Parija (2011) [54] stated that leaf area index increases with increased rate of nitrogen application. Effa *et al.* (2011) [17] found an significant increase in growth parameters with application of 120 kg ha^{-1} of nitrogen compared to control in maize Mehta *et al.,* (2011) [49] disclosed that application of 225 kg ha^{-1} of nitrogen increased plant height, relative growth rate, crop growth rate, leaf area index and dry matter production in maize and was statistically on par with 250 kg ha^{-1} than control and lower levels from his experiment**.** Stem girth, more of number leaves per plant, crop growth rate, leaf area index and dry weight were found to be statistically significant with increasing levels upto 150 kg ha^{-1} of nitrogen in maize Jeet *et al.,* (2012) [27]. Singh observed that plant height and dry matter production in sweet corn increases with increasing level from 120 to 150 kg ha^{-1} and remained on par from increasing nitrogen rate than 120 kg ha^{-1}. Application of nitrogen at 150 kg ha^{-1} gave significant increase in leaf area index, earliness in silking and maturity than lower levels in maize Verma *et al.,* (2012) [75]. Raskar *et al.,* (2012) [60] surmised that 120 and 160 kg ha^{-1} of nitrogen application gave plant height which was on statistically on par in maize. Bassava reported that plant height and leaf area index were maximum with application of nitrogen at 240 kg ha^{-1} than other levels from his research trial. The results are in conformation with the findings of Quaye *et al*., (2009) [55]. Brar (2013) [11] disclosed from his findings that nitrogen doses had remarkable increase in leaf index. Jena *et al.,* (2013) [28] reported that application of 240 kg N ha^{-1} than lower levels significantly increased growth parameters and 50% days to flowering earlier. Amanullah *et al*., (2014) [2] confirmed that growth and growth attributes of maize increases with higher nitrogen application rates. Joshi *et al.,* (2014) [29] from his two years experiment documented that application of nitrogen 100 kg ha^{-1} to maize significantly gave higher plant height, number of leaves plant, leaf area, fresh weight, dry weight and chlorophyll index at all growth stages than 50 kg and 100 kg of nitrogen application. Kaur and Vashisth (2015) [32] documented that plant height was higher (168.7cm) with 150 kg ha^{-1} of nitrogen application than control (147.9 cm) and number of leaves per plant was 13.9 which is higher with control (12.3). Imran *et al*., (2015) [25] documented significant increase in leaf area index (2.76) with 210 kg ha^{-1} of nitrogen application than lower levels. Jena *et al.,* (2015) [28] disclosed that application of nitrogen at 240 kg ha^{-1} in quality protein maize gave higher plant height and leaf area index than control and lower levels from his research**.** Ashraf *et al.,* (2016) [3] documented significant increment in growth parameters such as plant height, leaf area index (LAI), crop growth rate (CGR) at all stages of crop growth with application of 250 kg ha^{-1} of nitrogen than lower levels and control. Growth parameters such as plant height, number of leaves per plant and leaf area index were higher with application of 150 kg ha^{-1} than lower levels and control Reddy *et al.,* (2019) [61].

Effect of nitrogen on yield parameters of maize

Shivay and Singh (2000) [64] registered positive difference in yield with increasing in higher levels of nitrogen rate up to 120 kg ha^{-1} than control in maize. Ayub *et al.,* (2003) [5] reported that higher levels of nitrogen application gave significant increase in green fodder yield. Blumenthal *et al.,* (2008) [10] stated that increasing level of nitrogen application aids in better grain filling and enhances integrity, strength of maize kernels. Kernel number per ear and number of kernels per row were higher with increased rate of nitrogen application was reported by Gungula *et al.,* (2007) [21] and Dwadi and Sah (2012) [15]. Das conceived that application of 120 kg N ha^{-1} registered higher number of cobs plant, number of rows cob, number of grains cob, grain yield and straw yield of maize when compared to lower levels from his study. Parija (2011) [54] disclosed that cob length increases with increase of nitrogen rate from 150 kg ha^{-1}. Hammad *et al.,* (2011) [22] divulged that application of 200 kg ha^{-1} N level is insufficient to gain optimal yield in semi-arid conditions in maize. Aulakh *et al.,* 2012 [4] from his research trial concluded that 150 kg ha^{-1} of N application gave significantly more number of grains per cob, seed index, shelling percentage as

well as grain yield and straw yield than lower levels as a result of adequate amount of nitrogen supplement gave better pollination reducing barrenness and better sink development capacity. Earlier reports were in conformation with results by researchers (Rana and Choudhary, 2006; Khanday and Thakur, 1991; Ramu and Reddy, 2007) [58, 36]. Jena *et al*., 2013 [28] documented that application of 240 kg N ha gave significantly higher grain yield 6383 kg ha and stover yield7050 kg ha which was 72.43% and 68.83% higher than control treatment from his experiment. Joshi *et al.,* (2014) [29] registered more number of grains, weight per cob, seed index and the grain yield, straw yield increased 4.78 % in maize by application of 100 kg ha^{-1} of nitrogen rather than 50 and 75 kg ha^{-1} from his two year research trial in maize. Carvalho *et al.,* (2012) [13] and Wasnik *et al.,* (2012) [76] also confirms these results from their experimentation in nitrogen levels. Kaur and Vashisth (2015) [32] reported that maximum seed index was obtained with 180 kg ha^{-1} of nitrogen than lower level of application. Tasseling and silking commences earlier with higher dose of nitrogen application 200 kg ha^{-1} in maize Shreshtha (2015) [66]. Dilip divulged that increased level of nitrogen application from 150 to 200 kg ha^{-1} gave higher yield than lower levels and control from his study. Higher cob length, cob diameter and number of grains rows/cob, number of grains per row, number of grains per cob, grain weight per cob, seed index, grain yield, biological yield and harvest index were significantly higher with 250 kg ha^{-1} of nitrogen application over lower levels and control in maize Ashraf *et al.,* (2016) [3]. Higher number of cobs per plant (1.01), cob length (17.9), cob girth (14.4), number of rows per cob (13.9), number of grains per cob (390.2), 1000 grain weight (299.5), shelling % (81.9) with application of 180 kg ha^{-1} of nitrogen which is statistically significant when compared to lower levels Kaur (2016) [31]. Reddy *et al.,* (2019) [61] registered higher grain yield and stover yield of maize with application of 150 kg ha^{-1} than lower levels and control.

Effect of nitrogen levels on quality parameters of maize

Leary and Rehm (1990) [41] disclosed that application of 225 kg ha^{-1} increases crude protein content in maize. Protein content in maize was found to be statistically higher with application of 200 kg ha^{-1} Sarwar (1993) [63]. Higher accumulation of total nitrogen in grain maturation increases the protein content of seeds and other quality parameters by triggering biochemical relations as a result of higher level application of nitrogen in maize Kamalakumari and Singaram (1996) [30]. Shivay and Singh (2000) [64] found crude fibre of maize kernel increases with increasing rate of nitrogen supplement to maize. Majumdar surmised that application of 100 kg ha^{-1} increased protein content of maize**.** Ayub *et al.* (2003) [5] reported that higher levels of nitrogen application gave significant increase crude protein content, crude fibre and total ash content from his study. Maurya *et al.,* (2004) [46] stated that 150 kg ha^{-1} of nitrogen application increases protein content of maize compared to no application from his study. Rasheed *et al.,* (2004) [59] found that protein content increased (9.9%) in grain with application of nitrogen at 150 kg ha^{-1} and 20 kg ha of sulphur in maize. Keskin *et al.,* (2005) [33] observed protein yield and crude protein content increases with increased level of nitrogen application upto 200 kg ha^{-1}. Increase in starch, sugar content, protein and crude protein content was recorded with increasing levels of nitrogen up to 150 kg N ha^{-1} in baby corn Muthukumar *et al.,* (2005) [51]. Hani *et al.,* (2006) [24] reported that protein content of maize grain was higher with application of 180 kg ha^{-1} of nitrogen. Application of 180 kg ha^{-1} of nitrogen enhanced significantly protein content, starch and carbohydrate Ram *et al.,* (2006) [56]. Meena *et al.,* (2007) [47] documented significant increase in protein content with application of 120 kg ha^{-1} compared with 80 kg ha^{-1} in maize. Bindhani *et al.,* (2007) [8] found that application of nitrogen with 120 kg ha gave significant increase in protein content in baby corn. Application of 200 kg ha^{-1} of nitrogen increases protein content of maize than lower levels Mishra *et al.,* (2009) [50]. Das reported that protein content of corn seeds, carbohydrate were significantly higher by application of 120 kg N ha^{-1} in baby corn. Carpici *et al.,* (2010) [12] recorded higher crude protein content with application of 400 kg ha^{-1} which was statistically on par with 300 kg ha^{-1}. Verma (2011) [74] observed that application of 150 kg ha^{-1} of nitrogen gave significant increase in protein content of maize than lower levels from his study. Protein content in maize was found with increasing nitrogen levels upto 300 kg ha^{-1}. Khan *et al.,* (2011) [35]. Aulakh *et al.,* (2012) [4] found that nitrogen application at 175 kg nitrogen ha^{-1} produced maximum protein content (11.2%) which is statistically significantly than 125 N ha (10.9%) and 100 N (10.5%). Application of nitrogen at 120 kg ha^{-1} documented significant increase in crude fibre, crude protein content and protein content in maize when compared to lower levels Mahdi *et al.,* (2012) [43]. Significant increase in protein content was registered with increasing levels of 150 kg ha^{-1} than lower levels in maize Jeet *et al.* (2012) [27]. Jaliya *et al.,* (2013) [26] stated that increasing levels of nitrogen increases the grain nitrogen concentration which is an integral part of protein synthesis and finally accelerating the protein content. Jena *et al.,* (2013) [28] documented that application of 240 kg N ha^{-1} highest protein content (11.35%) lower levels compared to other treatments, while lowest protein content was obtained with control plot of nitrogen (9.14%) from his study. Tamat *et al.,* (2019) [72] reported higher crude protein content and fibre content with application of 120 kg ha^{-1} of nitrogen over control in maize. Similar results were reported by Getachew *et al.,* (2013) [18].

Effect of nitrogen levels on economics of maize

Thakur *et al.,* (1997) [73] documented that application of 200 kg ha^{-1} of nitrogen gave 117.7% in maize than lower levels but benefit cost ratio was higher with 150 kg ha^{-1}. Pandey *et al.,* (2000) [52] reported that application of nitrogen net returns and benefit cost ratio increased with 120 kg ha^{-1} than lower doses. Application of nitrogen with 120 kg ha^{-1} recorded 289.2% in net returns and 235.2% in benefit cost ratio compared to control in baby corn Bindhani *et al.,* (2005) [9]. Maurya *et al.,* (2005) [45] noticed that net profit and benefit cost ratio was higher with increasing levels of nitrogen to 150 kg ha^{-1} in maize. Panwar and Munda (2006) [53] registered significant increase in net returns of 63.2 % compared to control with application of 120 kg ha^{-1} of nitrogen in baby corn from his study with different nitrogen levels. Ram *et al.,* (2006) [56] documented higher gross income, net returns and benefit cost ratio with 180 kg ha^{-1} of nitrogen application compared to lower doses. Bindhani *et al.,* (2007) [8] recorded higher net returns and benefit cost ratio by application of nitrogen to 120 kg ha^{-1} from his study. Net returns and benefit cost ratio was statistically higher when compared to no application and lower doses Meena *et al.,* (2007) [47]. Net returns was 109.5% with application of nitrogen at 120 kg ha^{-1} over control treatment in maize and other levels from his two years of experimentation. Significant increase in benefit cost ratio was higher with application of 120 kg ha^{-1} in fodder

maize over lower doses and control Mahdi *et al.,* (2012) [43]. Singh *et al.,* (2012) [42] disclosed net returns and benefit cost ratio were higher with 120 kg ha^{-1} of nitrogen application and was statistically on par with application of 150 kg ha^{-1} in sweet corn. Application of nitrogen at 150 kg ha^{-1} registered highest net returns and benefit cost ratio in quality protein maize hybrids with his study with different levels Jeet *et al.,* (2014) [27]. Reddy *et al.,* (2019) [61] documented higher net returns (59108 ha) and benefit cost ratio (1.63) with 150 kg ha^{-1} of nitrogen application than control treatment with lowest net returns (Rs. 2518.70 ha-1) and benefit cost ratio (0.08).

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