Comprehensive Research and Reviews in
Multidisciplinary Studies
Journal homepage: https://crrjournals.com/crrms/
ISSN: 2961-3582 (Online)

(RESEARCH ARTICLE)

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A review of the determination of nitrogen fertilizer levels for maize in different ethiopian agro-ecologies

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Comprehensive Research and Reviews in Multidisciplinary Studies, 2022, 01(01), 070–074

Publication history: Received on 12 July 2022; revised on 26 August 2022; accepted on 29 August 2022

Article DOI: https://doi.org/10.57219/crrms.2022.1.1.0027

Abstract

Fertilizers need to be used judiciously to avoid negative, undesirable impacts on ecology and ensure the sustainability of agricultural production systems. Accordingly, site-specific nutrient management approaches aim to achieve efficient fertilizer use, which increases profitability for farmers and results in high production per unit of area applied. Hence, the objective of this review was to investigate the determination of optimum nitrogen fertilizer rates for maize production in different agro-ecologies in Ethiopia. As several research findings have shown, the application of different nitrogen fertilizers significantly affects various aspects of growth, yield, and yield components of maize crops. Based on this, the review showed that growth, yield, and yield parameters of maize crops increased with increasing rates of nitrogen fertilizer. The review showed that the highest growth, yield, and yield-related parameters of maize in Ethiopia's different agro-ecologies were obtained from 65 kg/ha to 138 kg/ha of nitrogen fertilizer. As found in this review, the response of the maize crop to nitrogen fertilizer gives a different reflection at a different location. It was concluded that nitrogen fertilizer recommendations should be given to site-specific locations. Therefore, rather than simply recommend a single rate of nitrogen fertilizer to different agro-ecology and soil types of the country, it is necessary to conduct soil test-based, plant tissue analysis, and the response of maize crops to nitrogen fertilizer correlated with site-specific locations are recommended to determine nitrogen fertilizer to attain optimum production and sustainable production of maize crops.

Keywords: Fertilizer; Maize; Application of nitrogen; Rate

1. Introduction

In a large portion of the world, people consume maize (*Zea mays* L.), a cereal crop that is also a significant source of fo dder for livestock. In addition to food and feed consumption, maize has a wide range of industrial applications as well; from food processing to the manufacturing of ethanol. Maize is one of the most important cereal crops cultivated in Ethiopia. It ranks second, after teff, in area coverage and first in total production. According to a 2013/14 survey, meher season postharvest crop production covered a total land area of about 12,407,473 hectares. Out of the total grain crop areas, 79% (9,848,746 hectares) were under cereals. Of this, maize covered 16% (about 1,994,814 ha) and 18% (44,186,225) quintals of grain yields (CSA, 2014).

Despite the large area under maize cultivation, the national average yield of maize is about 3.2 t/ha (CSA, 2014). This is by far below the world's average yield, which is about 5.21 t/ha (FAO, 2011). This yield gap of maize is attributed to a number of factors like the frequent occurrence of drought, declining soil fertility, poor agronomic practices, limited use of input, insufficient technology generation, and lack of credit facilities, poor seed quality, disease, insect pests, and weed infestation (CIMMYT, 2004)

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Fertilizers need to be used judiciously to avoid negative, undesirable impacts on ecology and ensure the sustainability of agricultural production systems. Among the nutrients, nitrogen (N) is one of the important nutrients that enhance the metabolic processes based on protein, leading to increases in vegetative, reproductive, and crop yields; thus, it is required in the largest amount from soil (Nasim et al., 2012). Nitrogen is readily absorbed by plants in the forms of nitrate (NO_3), urea (CO(NH2)2), and ammonium ions ($NH4^+$). Compared to other cereals, maize requires higher inputs of nitrogen fertilizer. Insufficient nitrogen applications will limit crop yield; however, excess nitrogen applications can reduce oil content and result in tall plants with large leaves that are more susceptible to lodging and disease. Accordingly, site-specific nutrient management approaches aim to achieve efficient fertilizer use, which increases profitability for farmers and results in high production per unit of area applied. Hence, the objective of this review was to investigate the determination of optimum nitrogen fertilizer rates for maize production in different agro-ecologies in Ethiopia.

2. Effect of Nitrogen on Plant Growth of Maize

2.1 Plant height

According to a study by Woldesenbet and Haileyesus (2016) in the Decha district in southwest Ethiopia, a rise in nitrogen levels causes plants to grow taller. They discovered that the lowest (347.33 cm) and tallest plants (360.66 cm) were grown in fertilized plots, respectively, and that the supply of 92 kg/ha nitrogen fertilizer resulted in a plant height advantage of 3.84% over unfertilized plots. According to Selassie's (2015) study on Alfisols in northwest Ethiopia, the rate of application that resulted in the most significant plant height observed at all stages was 90 kg/ha nitrogen fertilizer.

However, Biya (2021) reports a considerable rise in plant height from 261.46 to 274.77cm, as well as an increase in N content from 69/69 to 138/69 kg/ha nitrogen fertilizer . He discovered that the highest plant height (274.77cm) obtained with 138/69 kg/ ha nitrogen fertilizer treatment was 5.08% greater than the lowest, and the study was conducted in Nada Sadacha, Southern Ethiopia. Similarly, in Getinet and Atnafu (2021), the application of 138 kg/ha nitrogen fertilizer from urea stable in splits resulted in the highest plant height (296.67 cm), whereas in Tiro Afeta, the application of 92 kg/ha N from urea stable in splits resulted in the highest plant height (306.00cm). The shortest plant heights (264.33cm and 231.00cm, respectively) were measured in unfertilized plots in the Kersa and Tiro Afeta Jimma zones in southwestern Ethiopia.

Tadesse and Kim (2016) found that increasing the rate of nitrogen application boosted height linearly and considerably in Ethiopia's Central Rift Valley. Plant height grew by 100% in Adami Tulu when the nitrogen rate was increased from 0 to 125kg/ha nitrogen fertilizer. Plant height differed significantly ($p < 0.01$) between N fertilizers rates applied to the maize plant at MARC. Increased plant height was seen after applying 125kg /ha nitrogen fertilizer, which resulted in a 39% increase in plant height when compared to the control treatment. In addition, according to Amenu Dereje (2019), plant height grows as the nitrogen level rises to the maximum nitrogen rate (138 kg/ha). A 138 kg/ha nitrogen application resulted in the tallest plant height (262cm). The control treatment had the shortest plant height (237.7cm), and the experiment was conducted in Nedjo, western Ethiopia.

2.2 Ear length

According to Woldesenbet and Haileyesus (2016), a rise in nitrogen levels results in an increase in ear length. The addition of 92 kg/ha nitrogen fertilizer resulted in the longest ear length (23.63 cm), while treatment with no fertilizer resulted in the smallest (22.63 cm). Zinachew and Sharma (2020) reported an increase in cob length with an increasing rate of fertilizer N application, with the highest cob length (16.04cm) recorded at a nitrogen fertilizer rate of 200 kg/ha, and the lowest cob length (13.11cm) recorded at a nitrogen fertilizer rate of no nitrogen application. Similar findings by Tadesse and Kim (2015) reported that increases in N rates increased ear length, with the highest rate of 125 kg/ha producing higher ear lengths (23.61 cm and 26.03cm), while shorter ear lengths (17.83cm and 16.4cm) were recorded in the plots that received the lowest rate of 0 kg/ha (control treatment) nitrogen fertilizer at Adami Tulu and MARC, respectively. When ear lengths were compared, a 125 kg/ha nitrogen fertilizer application resulted in a 32% larger ear than the control treatment, which received no fertilizer during the study. In addition, in the study conducted by Dereje et al. (2019), the maximum ear length (26.98cm) was recorded at the application of 138 kg nitrogen per hectare, while the minimum ear length (15.58cm) was recorded from the control treatment.

3. Effect of Nitrogen on Yield and Yield Related Parameters

3.1 Number of kernels per ear and number of ears per plant

The application of 200 kg/ha nitrogen fertilizer produced the highest mean value (451.8), while the treatment that received no fertilizer produced the lowest mean value (295.43) (Selassie, 2015). They reported that, in comparison to unfertilized plots, the treatment improved the mean value of the number of kernels per ear by roughly 52.93%. Likewise, research conducted by Zinachew and Sharma (2020) showed that there was an increase in the number of kernels per ear with an increase in the application rates of nitrogen fertilizers. Similarly, the largest value (621.68) was recorded from the application of 200 kg/ha nitrogen fertilizer, while the lowest value (416.9) was obtained from the control. They found that the application of 200 kg/ha nitrogen fertilizer increased the number of kernels per ear by 49.12% over the control treatment.

As Dereje et al. (2019) reported, the maximum number of ears per plant (1.292) was obtained from the application of 92 kg nitrogen per hectare, whereas the lowest number of ears per plant (1.02) was recorded from the treatment without nitrogen. These findings are supported by Tadesse and Kim (2015), who reported that the maximum mean value of the number of ears per plant (1.33)was recorded from the application of 75 and 125 kg/ha nitrogen inorganic fertilizer, while the lowest mean value of the number of ears per plant (1.07) was obtained from the unfertilized plot at Adami Tulu. Similarly, the maximum mean value of the number of ears per plant (1.27) was recorded from the application of 75 kg/ha nitrogen inorganic fertilizer, while the lowest mean value of the number of ears per plant (1.0) was obtained from the unfertilized plot at MARC.

3.2 Grain Yield

During the 2017–18 main cropping season, a study conducted in Nada Sadacha woreda of Jimma Zone, Southwest Ethiopia, showed a significant increase in crop yield from 7.31 to 8.66 t/ha when nitrogen levels ranged from 69 to 138 kg/ha (Biya, 2021). Also, this finding showed that in comparison to the control (69 N kg/ha), grain yield dramatically improved by 18.47 percent. Furthermore, Getinet and Atnafu (2021) conducted another study in the Kersa and Tiro Afeta Districts of Southwestern Ethiopia during the 2017-2018 cropping season, which revealed that the highest grain yields (7067.4 kg/ha at Kersa and 8178.1 kg/ha at Tiro Afeta) were obtained by using 138 kg/ha of nitrogen fertilizer, while the lowest grain yields (3251.4 and 3145.4 kg/ha) were recorded from controls. However, according to a study conducted in Decha district, Southwestern Ethiopia, Woldesenbet and Haileyesus (2016), the highest yield was obtained from the application of 69 kg/ha nitrogen fertilizer, while the lowest yield was obtained from the treatment that was not treated with nitrogen fertilizer.

A study in the Central Rift Valley of Ethiopia conducted by Tadesse and Kim (2015) showed that the application of 75kg/ha nitrogen fertilizer gave a higher yield (8.07 t/ha), increased by 82% over the control treatment at MARC, while the addition of 100kg/ha nitrogen fertilizer gave the highest yield (6.55 t/ha) and a yield gain of 114.9% over the control treatment at Adami Tulu had been observed. Another study by Bekere (2022) during the main cropping season of 2020 at two locations (Dera and Melkassa) in the Central Rift Valley of Ethiopia revealed that the variety WE8206 produced the highest grain yield (8390 kg/ha) at a plot that was treated with 65 kg/ha nitrogen fertilizer while the standard check variety MH138Q produced the lowest grain yield (3489 kg) at the control plot. Also, these studies showed that the application of 32.5 and 65 kg/ha nitrogen fertilizer, respectively, enhanced the grain production of this hybrid (WE8206) by 47.31% and 14.63% compared to the control plot. In other study, Mosisa et al. (2022) conducted a study at Haramaya University in eastern Ethiopia; the findings revealed that the treatment that got rates of 92 kg/ha nitrogen fertilizer obtained the maximum grain yields.

In the study conducted by Zinachew and Sharma (2020) in Denba Gofa, Southern Ethiopia, the highest yield (8251.8 kg/ha) was obtained by applying 200 kg/ha of nitrogen fertilizer, while the lowest yield (4648.1 kg/ha) was obtained from non-nitrogen-treated treatments. By the same token, Selassie (2021) conducted another study in Alfisols of North-western Ethiopia, which revealed that using 200 kg/ha of nitrogen fertilizer yielded the best grain yields (5911.19 kg/ha), whereas controls yielded the lowest grain yields (3655.61 kg/ha). These studies also revealed that grain yield increased by 61.7% when compared to the control. However, as Dereje et al. (2019) conducted research in Nedjo, western Ethiopia, the application of 92kg/ha nitrogen fertilizer gave the highest yield (8145 kg/ha), while the lowest grain yield (4154 kg ha-1) was achieved from the control treatment, which was not treated with any fertilizer. Moreover, another study by Abera et al. (2017) showed that the application of half (55 kg/ha) and full (110 kg/ha) prescribed nitrogen fertilizer yielded mean grain production advantages of 31 and 41% above control, respectively, in mid-altitude regions of western Ethiopia.

3.3 Stover and above-ground biomass yield

Tadesse and Kim (2015) found that the N fertilizer rate applied had a significant (P < 0.01) effect on maize stover yield, with a constant increase in stover yield corresponding to an increased N fertilizer rate; the highest stover yield was obtained by applying the highest N rate (125kg N ha-1) at both sites, with a 68% increase in Adami Tulu and a 45% increase in MARC over the control treatment, which was not treated with any fertilizer during the experiment. According to Mosisa et al. (2022), the highest stover productivity was obtained for a nitrogen fertilizer rate of 92 kg/ha. On the other hand, they claimed that the treatments that got 23 kg/ ha nitrogen fertilizer exclusively at the vegetative phases, half at sowing and half at the vegetative stages, and one-third dose at each of the sowing, vegetative stages, and tasseling application, obtained the lowest stover yields. In view of that, Selassie (2015) showed that the addition of 90 kg/ha nitrogen fertilizer provided a higher dry stubble yield (9094.42kg/ha), increasing by 69.16% over the control treatment, while the application of control treatment nitrogen fertilizer gave the minimum stubble yield (5376.36 kg/ha) had been observed.

According to Dereje et al. (2019), the treatment that got 138 kg/ha nitrogen fertilizer produced the most aboveground dry biomass (35701 kg/ha) while the unfertilized plot had the lowest dry biomass output (24372.2 kg/ha). This finding is similar to Zinachew and Sharma's (2020) report, which showed that the biomass yield increased from 25332.7 kg/ha in control to 37481.2 kg/ha with a nitrogen level of 200 kg/ha, representing a nearly 50% increase and that the biomass yield increased significantly with each successive level of N from 0 to 200 kg/ha. In another study, the application of 138 kg N ha-1 from urea stable in two splits resulted in the highest values for biomass yield (21.67 t ha-1 and 21.42 t ha-1), while the lowest biomass yields (14.75 t ha-1 and 11.39 t ha-1) were recorded from control plots in Kersa and Tiro Afeta, respectively (Getinet and Atnafu, 2021). A study conducted by Selassie (2015) showed that the application of 200 kg/ha nitrogen fertilizer gave a higher biomass yield (14258.35 kg/ha), increasing by 66.28% over the control treatment, while the addition of 0 kg/ha nitrogen fertilizer gave the minimum biomass yield (8575.01 kg/ha) had been observed.

4. Conclusion

As several research findings have shown, the application of different nitrogen fertilizers significantly affects various aspects of growth, yield, and yield components of maize crops. Based on this, the review showed that growth, yield, and yield parameters of maize crops increased with increasing rates of nitrogen fertilizer. The review showed that the highest growth, yield, and yield-related parameters of maize in Ethiopia's different agro-ecologies were obtained from 65 kg/ha to 138 kg/ha of nitrogen fertilizer. As found in this review, the response of the maize crop to nitrogen fertilizer gives a different reflection at a different location.

It was concluded that nitrogen fertilizer recommendations should be given to site-specific locations. Therefore, rather than simply recommend a single rate of nitrogen fertilizer to different agro-ecology and soil types of the country, it is necessary to conduct soil test-based, plant tissue analysis, and the response of maize crops to nitrogen fertilizer correlated with site-specific locations are recommended to determine nitrogen fertilizer to attain optimum production and sustainable production of maize crops.

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