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Response of Onion (*Allium cepa* L.) to Nitrogen Fertilization in Different Agroecology of Ethiopia: A Review

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Abstract

The onion is one of the most significant vegetables grown by smallholder farmers in Ethiopia, primarily as a source of cash and flavor. However, Ethiopia's onion yield is low when compared to other countries such as the Republic of Korea, the United States, the Netherlands, Japan, and Egypt. As a result, the objective of this review was to find out the response of onion (*Allium cepa* L.) to nitrogen fertilizer in various Ethiopian agroecologies. According to the review, almost every onion parameter responded significantly to nitrogen fertilizer. The largest onion yield was obtained from plots treated with the highest nitrogen fertilizer rate, whereas the lowest onion yield was obtained from plots treated with no nitrogen fertilizer rate. Similarly, nitrogen fertilizer levels ranging from 0 to 250 kg/ha boosted onion yield across different agroecologies in Ethiopia. However, this review discovered that the amount of nitrogen applied and onion crop responses to nitrogen varied from place to place and from agroecology to agroecology, and thus blanket fertilizer recommendations are unnecessary in this notion. Thus, determining the appropriate amount of nitrogen fertilizer to apply is critical for limiting the danger of nutrient loss while also increasing yields from crops. This review also found that the experiment should be repeated across locations and seasons, with intra-row spacing and nitrogen rates included when recommending fertilizer. It might be concluded that future fertilizer recommendations should be based on soil test-based studies, crop reactions to fertilizer, and the country's agroecology.

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nitrogen fertilizer, onion, fertilizer rate, yield, seeds, allium plant.

Introduction

The onion (*Allium cepa* L.) is a member of the Alliaceae family and one of the world's greatest vegetables (Gambo *et al.*, 2008). It is a vegetable crop cultivated for its pungent and spicy bulbs. As stated by Rabinowitch and Currah (2002), except for the seeds, allium plant parts can be eaten by humans. It is thought to have originated in southwest Asia and spread around the world. It has been cultivated as an annual for bulb production for approximately 4700 years. As reported by the FAO (2019), China is the world's leading producer of onions, followed by India and the United States.

Around 2.37 million tons of bulbs were produced in Ethiopia from 22,035.8 hectares of land, with an average yield of 10.75 t/ha (CSA, 2011). Similar to Desalegne and Aklilu (2003), the onion is one of the most valuable crops produced by smallholder farmers, predominantly as a source of cash income and for flavoring purposes. The crop is thought to be used on a greater scale in the country than any other vegetable crop (Joosten *et al.*, 2011). As per FAO STAT (2012), however, Ethiopia's onion productivity is poor when compared to other countries such as the Republic of Korea (66.15 t/ha), the United States (56.13 t/ha), the Netherlands (51.64 t/ha), Japan (46.64 t/ha), and Egypt (36.16 t/ha).

The application of suitable agronomic management has undeniably contributed to enhanced crop yields. According to many reports, low vegetable yields in Ethiopia are due to reduced soil fertility and inadequate agronomic practices, such as the imbalanced use of fertilizers (Lemma and Shimeles, 2003).

A better understanding of the onion plant's nutrient needs is required in order to design management strategies that maximize fertilizer use of the onion and thereby increase profits for farmers with superior bulb quality and yield. Marschner (1995) reported that nitrogen is a vital nutrient for plant growth and development since it is a component of proteins, enzymes, and vitamins, as well as a critical element for photosynthetic activity and chlorophyll.

The correct nitrogen rate for onion-growing areas is critical to enhancing productivity and production. In light of these findings, this review was initiated in order to determine the response of onion (*Allium cepa* L.) to nitrogen fertilization using different agroecologies in Ethiopia.

The overview of nitrogen

The element nitrogen, which is the most frequently growth-limiting nutrient, is now known to be an important ingredient in metabolically active substances such as amino acids, proteins, co-enzymes, and certain non-pertinent ones. It is an integral part of cell components and accounts for 7% of total plant dry matter. Also, it is one of the most complex in terms of properties, existing in soil, air, and water in both inorganic and organic forms, and thus provides the most challenging difficulty in creating fertilizer recommendations (Archer, 1988).

Nitrogen accounts for around 5 to 6% of soil organic matter by weight, and it enters the soil in both symbiotic and non-symbiotic forms from the atmosphere. As such, it is essential in all of the plant's living tissues. Absolutely nothing else promotes strong plant development like nitrogen. Protein abundance causes the leaves to grow in size, which leads to an increase in carbohydrate synthesis.

Influence of nitrogen on yield and yield traits of onion

Marketable yield (t/ha)

Onion is a heavy consumer, which calls for a lot of nitrogen. Excess nitrogen can cause excessive vegetative growth, delayed maturity, higher susceptibility to diseases, decreased dry matter contents, and decreased storability, leading to a lower yield and quality of marketable bulbs. On the other side, when nitrogen levels are low, onions and shallots can be severely stunted, with reduced bulb size and marketable yields. As a result, low levels of this nutrient in the soil have a negative impact on the yield, quality, and storability of onion and shallot bulbs. Onion bulb size is proportional to planting density, with smaller bulbs forming at closer spacing.

Messele (2016) conducted a field experiment from March to July 2015 at the Menschen für Menschen Foundation Agro-Ecology Department demonstration site in Harare National Regional State, Ethiopia, to evaluate the nitrogen and phosphorus rates for optimum onion (*Allium cepa* L.) productivity, growth, and quality. The experiment used two nitrogen rates (0 and 50 kg/ha) and two phosphorus rates (0 and 75 kg/ha). As such, he observed that nitrogen treatment had a substantial effect on the majority of the investigated attributes, although phosphorus fertilization and the interaction effect between nitrogen and phosphorus did not. The experiment demonstrated that plots that received 50 kg/ha nitrogen had the highest total and marketable bulb yields (3.72 kg/4 m^2) and (2.73 kg/4 m^2), respectively, while treatments getting no fertilizer had the lowest total and marketable bulb yields (1.4 kg/4 m^2) and (0.4 kg/4 m^2). Additionally, the findings of this experiment proved that applying 50 kg/ha nitrogen enhanced total and marketable bulb yields by nearly 46.2% and 60.4%, respectively, beyond the control. By Gessesew *et al.*, (2015), a field study was done in 2013 between January and June with irrigation at the Gode Polytechnic College Demonstration Farm in Somali National Regional State, south-eastern Ethiopia.

The treatments contained six nitrogen fertilizer rates (0, 46, 69, 92, 115, and 138 kg/ha) and a total of four levels of intra-row spacing (7.5, 10, 12.5, and 15cm). Accordingly, they found that treatments with 138 kg/ha nitrogen and 7.5cm intra-row spacing produced the maximum marketable yield (50.88 t/ha), after which they used 115 kg/ha nitrogen and 7.5cm intra-row spacing. The treatments with no nitrogen fertilizer application and

15cm intra-row spacing had the lowest marketable bulb yield (11.62 t/ha), followed by 12.5cm intra-row spacing at the same nitrogen level (14.10 t/ha).

In Arba Minch district, Gamo zone of southern Ethiopia, the field experiment was conducted to determine the effect of the irrigation interval and nitrogen rate on growth, yield, and yield components of onion (Bombay Red variety) during the 2018/19 cropping season (Tadesse *et al.,* 2022). The treatments included four nitrogen levels (0, 50, 100, and 150 kg/ha) and four irrigation intervals (three, six, nine, and twelve days of crop water demand, or ETc). They noticed that the 3 and 6 day irrigation intervals combined with 100 and 150 kg/ha nitrogen produced statistically similar marketable yields (33.2–34.1 t/ha), which were, in turn, significantly higher than yields from the other combinations. This was due to the interaction effect of irrigation interval and nitrogen rate. A greater marketable bulb yield (30.2 t/ha), net return (Birr 288,458), and marginal rate of return (8586%) were also produced by the irrigation at 6-day intervals when paired with 100 kg/ha nitrogen. They came to the conclusion that improved productivity and profitability of onions (Bombay Red variety) at Arba Minch, southern Ethiopia, may be advised by irrigation comparable to ETc at an interval of 6 days and nitrogen at a rate of 100 kg/ha.

Etana *et al.,* (2019) studied the effects of applying nitrogen fertilizer on the growth, yield, quality, and storage life of irrigated onions during the dry period at Jimma University College of Agriculture and Veterinary Medicine in South Western Ethiopia. The nitrogen levels in the treatments were 0, 50, 100, and 150 kg/ha. In consideration of this, this finding indicated that nitrogen fertilizer had an extremely significant ($P < 0.01$) effect on marketable bulb yield. They observed that applying nitrogen at 150 kg/ha gave rise to the highest marketable bulb yield (16.93 t/ha), while applying nitrogen at 0 kg/ha yielded the lowest marketable bulb yield (12.31 t/ha). When weighed against the control treatment, taking 150 kg/ha of nitrogen fertilizer led to a 37.53% increase in marketable bulb yield.

As reported, Alebachew *et al.,* (2019) conducted research in Amhara Region, northeastern Ethiopia, to figure out the most suitable nitrogen rate and intra-row spacing for economical onion production in an irrigated farming system. The nitrogen application rates (0, 41, 82, and 123 kg/ha) and intra-row spacing (6, 8, and 10 cm) were varied. Furthermore, the analysis of variance showed that the main and interaction effects of nitrogen and intra-row spacing have a highly significant influence on onion marketable yield. Hence, applying a dose of 123 kg/ha nitrogen to narrowly spaced plants (6 cm) brought about the highest marketable bulb yield (37.48 t/ha), increasing the marketable yield by not far off 126.9% compared to the yield obtained from the treatment combination of 10 cm intra-row without nitrogen. In another study, Agumas *et al.,* (2014) conducted experiments in Ribb and Koga irrigation schemes in the Amhara region, northwestern Ethiopia, during the 2010 and 2011 production seasons, with the purpose of identifying the optimum rates of nitrogen and phosphorus fertilizers for onion production at Ribb and Koga irrigation schemes in the region. Treatments also included five nitrogen levels (50, 100, 150, 200, and 250 kg/ha) and three phosphorus levels (20, 40, and 60 kg/ha). They identified that for onion production at Ribb, applications of 150 kg/ha nitrogen with 20 kg/ha phosphorus as the first option and 250 kg/ha nitrogen with 20 kg/ha phosphorus as the second option were suggested. The first option at the Koga irrigation scheme is an application of 100 kg/ha nitrogen and 60 kg/ha phosphorus. Applications of 50 kg/ha nitrogen and 60 kg/ha phosphorus are advised as a secondary alternative.

In the following investigation, a field study was carried out by Gebretsadik and Dechassa (2016) at the Well Foundation Farmers' Training Center located within the Shire Tigray Region of Ethiopia's northern part to examine the effects of nitrogen fertilizer rates and intra-row spacing on the yield of onion (*Allium cepa* L.). The treatments included four doses of nitrogen (0, 50, 100, and 150 kg/ha), four intra-row spacing (4, 6, 8, and 10 cm), and the same inter-row spacing (20 cm). Based on the aforementioned, it has been found that the best marketable yield (31.455 t/ha) was recorded at 100 kg/ha nitrogen, while the cheapest marketable yield (16.588 t/ha) was documented at 0 kg/ha nitrogen. Marketable fresh bulb production rose significantly by 89.63% above control when the rate of nitrogen was raised from 0 to 100 kg/ha. In order to achieve the highest yield, they came to the conclusion that the Onion Bombay Red cultivar should be planted in the Shire region during the rainy season at an ideal spacing of 6 cm x 20 cm with an application of 100 kg/ha nitrogen. Similar to this, Gebretsadik and Dechassa (2018) conducted a study in the Tahtay Koraro district of Tigray Regional State, northern Ethiopia, to investigate the impact of nitrogen fertilizer and intra-row spacing on the growth and yield of onions. The treatments had four levels of nitrogen (0, 50, 100, and 150 kg/ha) and four levels of intra-row plant spacing (4, 6, 8, 10, and 20 cm). Marketable bulb yield was considerably ($P < 0.01$) impacted by nitrogen as the main effect. The marketable yield ranged from 16.588 to 31.455 t/ha, with 100 kg/ha of nitrogen being the highest marketable yield. The fresh bulb yield increased by 85% when the nitrogen rate was increased from 0 to 100 kg/ha. They reached the decision that 100 kg/ha of nitrogen provided the best fresh marketable bulb yield and that increasing the nitrogen rate beyond this rate was not necessary to produce a crop yield. In the study investigated by Guesh (2015) in the Central Zone of Tigray, Northern Ethiopia, both the greatest total (39.69 t/ha) and marketable bulb yields (39.51 t/ha) were attained by applying 82 kg/ha of nitrogen-based fertilizer at the intra-row spacing of 5 cm, while the fewest total (18.89 t/ha) and marketable bulb yields (17.93 t/ha) were gathered from non-nitrogen-treated treatments at the intra-row spacing of 12.5 cm and 2.5 cm, respectively. He ended up agreeing that the application of 82 kg/ha nitrogen and the intra-row spacing of 10 cm, which was ideal for growing the crop in the Central Zone of Tigray, resulted in the largest net profit with the lowest cost.

In 2012, Tsegaye *et al.,* (2016) examined the effects of various nitrogen levels and irrigation schedules on onion (*Allium cepa* L.) crop yield as well as components of yield in the Hawassa area district in southern Ethiopia. According to this study, the nitrogen level had a significant ($P < 0.001$) impact on the marketable onion yield. Therefore, 0 and 100 kg/ha of nitrogen were used to produce the lowest (16.51 t/ha) and maximum (26.23 t/ha) onion marketable bulb yields, respectively. Additionally, the marketable yield ranged from 15.48 t/ha at 25% ETc to 27.59 t/ha at 100% accessible soil moisture, which was statistically equivalent to the marketable bulb yield obtained at 75% ETc. The results of this study showed that irrigation and nitrogen have an impact on the marketable bulb yield of onions. Also, Tezera *et al.,* (2023) conducted a field experiment on clay loam soil at the test site of the Melkassa Agricultural Research Centre in the Central Rift Valley, Ethiopia, to establish the best nitrogen fertilizer rate and soil moisture level for onion yield and water productivity. Three soil moisture levels (100% ETc, 75% ETc, and 50% ETc) and four nitrogen fertilizer rates of 23, 46, 69, 92, and no nitrogen are used in the treatments. In a comparable manner, nitrogen fertilization treatments had a significant effect on onion bulb yield. With enhanced nitrogen fertilization, onion bulb yield improved considerably. The greatest mean bulb yield of 30.1 t/ha was reached at the 92 kg/ha nitrogen rate, whereas the lowest mean bulb yield of 20.1 t/ha was produced when no nitrogen rate was used. With respect to irrigation, the maximum average bulb yield was achieved at full irrigation, while the lowest average bulb yield was achieved at 50% deficit irrigation. Increased deficit irrigation levels of 0 to 25 and 50% resulted in yield losses of 6.3 and 20.3%, respectively.

Unmarketable (t/ha)

Guesh (2015) discovered that the combined effect of intra-row spacing and nitrogen fertilizer levels greatly influenced unmarketable bulb yield. The maximum value of unmarketable bulb yield was obtained without nitrogen fertilizer and 2.5 cm intra-row spacing. On the contrary, the lowest unmarketable bulb yield was obtained when onion plants were given fertilizer with 123 kg/ha nitrogen and planted at intra-row spacing of 5.0 cm, 7.5 cm, 10 cm, and 12.5 cm. In a similar way, Alebachew *et al.,* (2019) found that applying 123 kg/ha nitrogen to the largest spaced (10 cm) plants resulted in the smallest unmarketable onion yield (0.28 t/ha), which was statistically equal to the combined effect of 123 kg/ha nitrogen and 8 cm intra-row spacing. The combination of absent nitrogen with 6 cm intra-row spacing, on the other hand, produced the largest unmarketable yield (1.05 t/ha), increasing unmarketable bulb production by almost 275% in relation to the treatment combination of 123 kg/ha nitrogen with 10 cm intra-row spacing. Additionally, treatments that were given the lowest nitrogen rate (0 kg/ha) showed the highest unmarketable yield (0.98 t/ha), while those that received the highest nitrogen rate (150 kg/ha) showed the lowest unmarketable yield (0.47 t/ha) (Etana *et al.,* 2019).

Total bulb yield (t/ha)

Crops with better grain yields may have higher nitrogen rates, according to several studies carried out in various areas of Ethiopian soils. For instance, in line with a study by Gebretsadik and Dechassa (2016), plots receiving the highest rate of nitrogen fertilizer (64 kg/ha) produced higher total bulb yields (32.84 t/ha), whereas plots having the lowest rate (0 kg/ha) produced the lowest total bulb yields (18.31 t/ha). The total bulb yield increased by more than 79.36% when the nitrogen rate was increased from 0 to 100 kg/ha. In an additional study by Gessesew *et al.,* (2015), the combined application of 138 kg/ha nitrogen with a closer spacing of 7.5 cm produced the highest total bulb yield (52.04 t/ha). This was followed by 115 kg/ha nitrogen and 7.5 cm intra-row spacing, which produced a total bulb yield of 47.83 t/ha. The plants that were planted at wider intra-row spacing of 15 and 12.5 cm, respectively, from treatment with no nitrogen fertilizer use produced the smallest bulb yields of 14.62 and 17.15 t/ha. Alebachew *et al.,* (2019) found that the treatment pairing of 123 kg/ha nitrogen alongside 6 cm intra-row spacing generated the highest total bulb of onion (37.97 t/ha), increasing total bulb yield by about 181% relative to the treatment combination of null nitrogen with 10 cm intra-row spacing.

Influence of nitrogen on onion growth parameters

Plant height (cm)

Crops with larger plant heights may have higher nitrogen rates, according to numerous research investigations carried out at various sites in Ethiopian soils. According to a study by Tadesse *et al.,* (2022), the greatest nitrogen fertilizer rate of 150 kg/ha led to greater plant heights (59.92 cm), whereas the shortest nitrogen fertilizer rate of 0 kg/ha (control treatment) led to the lowest plant heights (51.67 cm) in the plots. In a different study, Messele (2016) found that treatments without fertilizer produced the lowest output (25.91 cm), but applications of 50 kg/ha of fertilizer containing nitrogen resulted in the maximum height of the plants (28.62 cm). In these experiments, when 50 kg/ha of nitrogen fertilizer was applied compared to the control, plant height increased by 10.5%. Similar to this, Etana *et al.,* (2019) showed that the application of nitrogen had an impact on the mean plant height at physiological maturity that was extremely significant ($p < 0.001$). They noticed that the largest average height (49.59 cm) was recorded from the plot that had 150 kg/ha of nitrogen. The greatest application of nitrogen at 150 kg/ha increased the mean plant height by about 12% as compared to the control (43.84 cm). The improvement in height with increased application of nitrogen could be attributed to its involvement as a building component in the synthesis of amino acids, as they link together to form proteins and make up metabolic processes necessary for plant growth.

In addition, Alebachew *et al.,* (2019) found that the tallest onion plant (58.08 cm) had been produced using 123 kg/ha nitrogen and 10 cm intra-row spacing, which resulted in plants growing 59% taller than plants grown with closer intra-row spacing and with no nitrogen fertilizer. The greater plant height associated with a higher nitrogen rate and wider spacing could be attributed to decreased competition among plants for nutrients and other growth factors at the widest intra-row spacing.

Bulb diameter (cm)

Tsegaye *et al.,* (2016) reported that changing the irrigation regime and nitrogen level boosted the mean bulb diameter of onions. At 100% ETc, for example, raising the nitrogen level from 50 to 150 kg/ha raised the mean bulb diameter of onions by 33 and 40%, respectively, whereas more increases had little or no impact. In another study, Gebretsadik and Dechassa (2018) discovered that increasing nitrogen rates resulted in a comparable rise in bulb diameter. They showed that the largest neck diameter (1.210 cm), which was produced by the greatest nitrogen rate, was measured at 150 kg/ha, whereas the narrowest neck diameter (0.93 cm), which was recorded in non-nitrogen application plots, was recorded in non-nitrogen application plots. Agumas *et al.,* (2014) found that the largest bulb diameter (18.68 cm) was created by applying 150 kg/ha of nitrogen, while the lowest bulb diameter (17.92 cm) was produced by the control treatment. However, they discovered that the best bulb diameter was achieved when 150 kg/ha of nitrogen were applied to the soil.

Leaf length (cm)

According to a study by Gebretsadik and Dechassa (2018), the main effect of nitrogen fertilizer is to considerably lengthen onion plants' leaves, as per the analysis of variance. Similar to the aforementioned, leaf length substantially increased by 18%, or 8 cm, in response to adding nitrogen from 0 to 150 kg/ha. The plots fertilized with 150 kg/ha nitrogen produced the longest bulbs (5.23 cm), while the control treatment produced the shortest bulbs (4.42 cm) (Etana *et al.,* 2019).

In a study conducted by Messele (2016), the plots that received the highest amount of nitrogen fertilizer (50 kg/ha) produced the longest leaves (29.73 cm), whereas the plots that received the lowest rate (0 kg/ha) produced the shortest leaves (28.00 cm). Additionally, compared to the control, the treatment of 50 kg/ha nitrogen enhanced leaf length by approximately 5.82% and by 29.73 cm.

Overall, according to the review, almost every onion parameter responded significantly to nitrogen fertilizer. The largest onion yield was obtained from plots treated with the highest nitrogen fertilizer rate, whereas the lowest onion yield was obtained from plots treated with no nitrogen fertilizer rate. Similarly, nitrogen fertilizer levels ranging from 0 to 250 kg/ha boosted onion yield across different agroecologies in Ethiopia. However, this review discovered that the amount of nitrogen applied and onion crop responses to nitrogen varied from place to place and from agroecology to agroecology, and thus blanket fertilizer recommendations are unnecessary in this notion.

Thus, determining the appropriate amount of nitrogen fertilizer to apply is critical for limiting the danger of nutrient loss while also increasing yields from crops. This review also found that the experiment should be repeated across locations and seasons, with intra-row spacing and nitrogen rates included when recommending fertilizer. It might be concluded that future fertilizer recommendations should be based on soil test-based studies, crop reactions to fertilizer, and the country's agroecology.

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