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Review Article

Optimizing Nitrogen Fertilizer Rates for Wheat (*Triticum aestivum* L.) in Different Soils of Ethiopia: A Review

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Abstract: Wheat is the main staple crop in terms of both production and consumption in Ethiopia. Despite the long history of wheat cultivation and its importance to Ethiopian agriculture, its average yield is still very low. As a result, the objective of this review was to review the effects of different nitrogen fertilizer rates on wheat production in different soil types in Ethiopia. In general, a number of research findings have exposed that the application of various nitrogen fertilizer rates significantly affects different characteristics of growth, yield, and yield-related characteristics of wheat crops. In accordance with this, the review showed that growth, yield, and yield parameters of wheat crops increased with increasing rates of nitrogen fertilizer. Moreover, the review revealed that application of nitrogen fertilizer at rates ranging from 23 kg N ha^{-1} to 360 kg N ha^{-1} gave the highest plant height, spike length, number of seeds per plant, and thousand Kernel weight, straw, and above-ground biomass and grain yield of wheat based on soil types and agroecology of the country. This review suggested that the response of the wheat crop to nitrogen fertilizer is not the same rate as that of other nitrogen fertilizers. Therefore, it is crucial to understand the nutritional status of the soil and plant nutrient uptake prior to applying fertilizer. In addition, different plant species and genotypes have different capacities for absorbing water, absorbing nutrients, and responding to stress. It concluded that the application of an appropriate amount of nitrogen fertilizer can be regarded as the main means to increase grain yield, improve uptake of nitrogen and the utilization effectiveness of wheat, reduce farmer costs, and reduce environmental contamination.

Keywords: Fertilizer Rate, Yield, Wheat, Nitrogen, Application

1. Introduction

Wheat is the main staple crop in terms of both production and consumption in Ethiopia. Ethiopia is the second-largest wheat (*Triticum aestivum* L.) producer in sub-Saharan Africa, after South Africa [12]. It ranks fourth after tef (Eragrostis tef), maize (Zea mays L.), and sorghum (Sorghum bicolor L. Moench) in area coverage and total production [6]. Despite the long history of wheat cultivation and its importance to Ethiopian agriculture, its average yield is still very low, not exceeding 3 t/ha [7], which is below the world's average of 3.4 t/ha [13]. The low yield of wheat in the country may be due to the use of low-yielding varieties, inadequate and erratic rainfall, diseases, and low soil fertility [2].

The wheat yield response to N fertilizer varies with the climatic conditions and soil N supply during the growing season [18]. They reported that a significant increase in grain yield has been observed with N fertilization, especially when soil N supply is low, but the application of a very high N rate can reduce grain yield by increasing lodging and disease incidence. However, nitrogen utilization efficiency is a measure of the amount of nitrogen taken up by plants and the amount of nitrogen lost to the environment from agricultural fields [21]. It was reported [19] that major cereal crop production is expected to have a low NUE (33%). Volatilization, leaching, and surface run-off can also limit the quantity of N accessible to the plant, reducing NUE [22]. Therefore, the application of an appropriate rate of nitrogen fertilizer is considered a primary means of increasing wheat grain yield, improving N uptake and nitrogen use efficiency, as well as the nitrogen harvest index [11]. Moreover, fully understanding crop and NUE responses to nitrogen fertilizer

applications is critical for designing site-specific soil nutrient management strategies and optimizing fertilizer recommendations [4]. Thus, the objective of this review was to review the effects of different nitrogen fertilizer rates on wheat production in different soil types in Ethiopia.

2. Influence of Nitrogen Fertilizer on Growth, Yield and Yield Components of Wheat

2.1. Growth Parameters

Plant Height (cm)

As many research findings exposed that, plant height increased consistently with increasing nitrogen rate. For instance, the findings [15] in southeastern Ethiopia showed that plant height increased as nitrogen levels rose from the control level to the maximum level. As a result, he found that the highest plant heights were recorded from the treatment with the highest N rate of 184 kg ha^{-1}, while the shortest plant height was recorded on plots without N application. Similar to the finding [25], reported that the maximum plant height (65.46 cm) was attained at 92 kg ha^{-1} of N rates, which was 15% higher than the control with a mean of 62.28 cm.

In another study conducted [1] in southern Ethiopia, it was found that increasing N rates led to a proportional increase in plant height. They exhibited that the highest N rate resulted in the tallest plant heights was recorded from 115 kg ha^{-1}, while the shortest plant height in non-nitrogen application plots. According to the research [24], applying nitrogen at rates ranging from 0 to 69 kg ha^{-1} resulted in an increase in plant height of between 3.3 and 7.8 cm when compared to the control.

Research done in Northern Ethiopia [23] stated that the tallest plant height (99.3 cm) was recorded from the treatment with the highest N rate of 184 kg ha^{-1}, whereas the shortest plant height was recorded on plots with 0 kg N ha^{-1}. Dargie, S. et al. [9] reported that an increase in N rate increased plant height; thus, the highest rate of 64 kg/ha produced the tallest plant heights (70.91 cm and 92.72 cm), whereas the shortest plant heights (61.80 cm and 86.09 cm) were recorded in plots that received a low rate of 0 kg ha^{-1} (control treatment) nitrogen fertilizer in Hawzien and Emba Alaje. When plant heights were compared, a 64 kg ha^{-1} nitrogen fertilizer application resulted in 14.74% and 7.70% taller plant heights than the control treatment, which received no fertilizer during the study, respectively.

Spike length (cm)

One of the wheat yield characteristics that affects grain yield is spike length. Grain yields may be higher in crops with longer spikes. In accordance with the above, a study [28] indicated that the longest spike length (8.4 cm) was recorded in response to the application of N at a rate of 300 kg ha^{-1}, but the shortest spike length (5.9 cm) was recorded from the control treatment. As a result, the increase in spike length caused by the greatest rate of N application was 42.4% more than the control. The longest spike length (8.31cm) was observed at treatments that received the highest level of nitrogen rate (87 kg ha^{-1}), while the shortest length spike (7.99 cm) was obtained from treatments that received the lowest level of nitrogen rate (52.5 kg ha^{-1}) [17]. In another study [9], it was stated that the highest and lowest spike lengths were recorded on plots treated with 96 kg N ha^{-1} as UREA Stabilize (7.38 cm) and on control plots with 0 kg N ha^{-1} (6.24 cm) at Hawzien and Emba Alaje, respectively.

2.2. Yield and Yield Components of Wheat

Grain yield (kg ha^{-1})

As noted in various research studies conducted at various locations in Ethiopian soils, crops with higher grain yield could have higher nitrogen rates. For example, a study conducted by Dargie, S. et al. [9] in the Vertisols and Cambisols of Tigray, Ethiopia, depicted that the highest rate of 64 kg ha^{-1} produced higher grain yields (1708.33 kg ha^{-1}), while the lowest grain yields (1102.73 kg ha^{-1}) were recorded in the plots that received the lowest rate of 0 kg ha^{-1} (control treatment) nitrogen fertilizer at Hawzien. The same way, the highest rate of 64 kg ha^{-1} produced higher grain yields (5467.9 kg ha^{-1}), while the lowest grain yields (4043.50 kg ha^{-1}) were observed in the plots that received the lowest rate of 0 kg ha^{-1} (control treatment) nitrogen fertilizer at Emba Alaje. They reported that, in comparison to unfertilized plots, the treatment increased the mean value of the grain yield by approximately 54.92% and 35.23%. Another study [17], showed that the application of 87 kg ha^{-1} of nitrogen fertilizer provided the highest grain yield (2897.02 kg ha^{-1}), while the lowest grain yield (2656.19 kg ha^{-1}) was recorded from the application of the lowest nitrogen fertilizer rate (52.5 kg ha^{-1}) in Burie District of West Gojjam Zone, North Western Ethiopia. In Ethiopia, a research [23] in the Mekdela district, South Wollo, revealed that 92 kg N per hectare was necessary to achieve a high grain yield (7415 kg ha^{-1}). In comparison to fertilizer applied at 92 kg ha^{-1} and the control, nitrogen fertilizer applied at a rate of 138 kg ha^{-1} had a 6.2 percent lower and 66.4 percent greater grain production. According to [28], the control treatment produced the lowest grain yield (1317.3 kg ha^{-1}), while the combined application of 200 kg N and 5000 kg ha^{-1} FYM produced the maximum grain production (5625.7 kg ha^{-1}) in Moretna Jiru Woreda, North Central Highlands of Ethiopia. However, he found that when nitrogen was supplied to the soil alone, the best grain production was attained with an application of 300 kg ha^{-1}. In addition, grain yield varied from 2620 kg ha^{-1} to 5194.16 kg ha^{-1}, with the lowest yield coming from the application of 92 kg ha^{-1} of nitrogen and 30 kg ha^{-1} of phosphorus and the highest yield coming from the application of 276 kg ha^{-1} of nitrogen and 90 kg ha^{-1} of phosphorus in Northwestern Ethiopia [3].

According to a study [26], cultivars CD94523, CDSS93Y107, and Bekelcha appear to produce high grain yields with an application of 69 kg N ha^{-1} that seems economical, while cultivars Ude, CDSS93Y107, and Ejersa appear to produce high grain yields with an application of 46 kg N ha^{-1} that appears to be equally as effective in Sinana,

South Eastern Ethiopia. Goda, D. D. [15] proposed that the highest and lowest grain yields were obtained in Lemu-Bilbilo District, Southeastern Ethiopia, with N rates of 184 kg ha^{-1} and control, respectively. Moreover, a study by [25] reported that the highest grain yield of 7300 kg ha^{-1} in Vertisols of Bale; highland, Southeastern Ethiopia, was achieved by increasing N at 92 kg ha^{-1} by 152% over the control.

A study done at the Sodo Agricultural Technical, Vocational, and Educational Training College farm in southern Ethiopia during the 2015 cropping season revealed that the highest grain productivity was attained from variety Danda'a' at a N rate of 138 kg ha^{-1} [1]. They ultimately decided that the variety Danda'a at a nitrogen rate of 138 kg ha^{-1} was the best to use for wheat production in Wolaita Sodo, Southern Ethiopia, and related agro-ecologies. According to a study by Teshome [24] in the Butajira district of the Guraghie Zone in southern Ethiopia, applying 46 kg of nitrogen per hectare increased grain yield by 115.3 and 38.5 percent in comparison to the control and 23 kg of nitrogen per hectare, respectively, but showed no significant difference with 69 kg of nitrogen per hectare.

In another study, the author [16] conducted a study in Amibara, Middle Awash, Ethiopia, and discovered that applying 92 kg ha^{-1} of nitrogen fertilizer yielded the highest yield (3738.2 kg ha^{-1}) whereas non-nitrogen-treated treatments yielded the lowest yield (2580. 5 kg ha^{-1}). In these studies, compared to the control, grain yield increased by 44.83%. As with Belete, F. et al. [5], who conducted a study on Vertisols in the highlands of central Ethiopia, the highest grain yield (5718.32 kg ha^{-1}) was obtained for the Menze variety at 360 kg N ha^{-1} in 2015. Also, on Vertisols in Ethiopia's Central Highlands, the highest mean grain yield (5063.7 kg/ha at Ginchi and 5110.4 kg ha^{-1} at Becho) was achieved with 90 kg N/ha, while the lowest grain yield was observed at zero nitrogen level at both locations [20].

During the off-season of 2020/21, the author [14] conducted a study in five districts in western Ethiopia: Horo, Jimma Geneti, Jimma Arjo, Wayu Tuka, and Degema. Accordingly, the highest yield (8900 kg ha^{-1}) of bread wheat was obtained when 23 kg N ha^{-1} and a 150 seeding rate were practiced in the Jimma Geneti district. In Horo district, however, the maximum yield was 6800 kg ha^{-1} at 92 kg N ha^{-1} and 125 seed rates. In Wayu Tuka District, the highest grain yield (4800 kg ha^{-1}) was obtained from the N treatment combination of 69 kg ha^{-1} planted at a seeding rate of 150 kg ha^{-1}. Similarly, in Jimma Arjo district, 23 kg N ha^{-1} was combined with seed rates of 150 and 175 to give a high grain yield of 4000 kg ha^{-1}. The highest grain yield (2500 kg ha^{-1}) was recorded in the Degem district when 69 kg N ha^{-1} and 175 kg ha^{-1} of bread wheat were utilized, respectively.

Another study conducted by [8] in Meta and Tullo districts of East Hararghe Zone in eastern Ethiopia; revealed that the highest grain yield (4880 kg ha^{-1}) was achieved at a rate of 90 kg N ha^{-1}. Furthermore, Yokamo et al. [27] reported that wheat responded to nitrogen application the best (96.5%), followed by barley (84.36%), teff (50.48%), maize (40.7%), and sorghum (23%). In the same manner as described above, they also reported that the yield of five cereal crops could linearly and considerably increase with nitrogen application rate and was maximum at >100 kg ha^{-1} (123.9%) and lowest (28.9%) where <30 kg ha^{-1} of nitrogen was applied.

Number of seeds per plant and thousand Kernel weight (g)

According to the research [15], the plots fertilized with 92 kg N ha^{-1} produced the highest grain spike^{-1} (57.4), whereas the control treatment produced the lowest grain spike. Further tests [25] revealed that the application of 92 kg N ha^{-1} resulted in the maximum number of seeds spike^{-1} of 28.4, with the quantity of seeds increasing by 59% over the control (17.85).

The thousand seed weight grew as the N fertilizer rate increased up to 46 kg ha^{-1} [24]. According to the research [17], the highest nitrogen fertilizer dose (87 kg ha^{-1}) produced the heaviest thousand kernel weight (37.47 g), while the lowest nitrogen fertilizer dose (52.5 kg ha^{-1}) produced the lightest thousand kernel weight (35.20 g). The author [28] reported that the combined application of nitrogen at a rate of 300 kg ha^{-1} and 5000 kg ha^{-1} FYM resulted in the highest thousand grain weight (52.29 g), whereas the control treatment resulted in the lowest thousand grain weight value (43.07 g).

Straw and above ground biomass yield of wheat (kg ha^{-1})

Considering that farmers are also interested in straw in addition to grain, biological yield is a significant consideration. Farmers in the highlands rely on the durum wheat plant's straw as a source of animal feed and for nutrient cycling. Similarly to the way, Tilahun Chibsa, B. et al. [25] asserted that when durum wheat plants were treated with 92 kg ha^{-1}, the maximum straw yield of 8000 kg ha^{-1} was reached, indicating an 88% increase over the control. According to the research [24], N fertilizer had a substantial effect on straw yield, and straw yield from plots treated with 69 kg N ha^{-1} was the highest, increasing straw performance by 172.2% compared to the control. Also the research [15] reported that straw yield increased with increasing N rates, with the lowest and maximum straw yields recorded from control plots (6991.8 kg ha^{-1}) and plots that received 184 kg N ha^{-1} (7735.5 kg ha^{-1}) correspondingly.

The maximum value (21100 kg ha^{-1}) was obtained from plots treated with nitrogen fertilizer at a rate of 184 kg ha^{-1}, while the lowest value (15900 kg ha^{-1}) was obtained from control plots; hence, biomass yield rose with increasing N rates [25]. In another study [16], biomass yield was found to increase with increasing nitrogen dosage rate; the maximum biomass yield (10818 kg ha^{-1}) was recorded from 92 kg ha^{-1} nitrogen treatment, and the minimum (7388.1 kg ha^{-1}) from the control treatment (no nitrogen applied).

3. Conclusion

Overall, as a number of research findings have exposed, the application of various nitrogen fertilizer rates significantly affects different characteristics of growth, yield, and yield-related characteristics of wheat crops. In accordance with this, the review showed that growth, yield, and yield parameters of wheat crops increased with increasing rates of nitrogen fertilizer. Moreover, the review revealed that

application of nitrogen fertilizer at the rate of 23 kg N ha^{-1} to 360 kg N ha^{-1} gave the highest plant height, spike length, number of seeds per plant, and thousand Kernel weight, straw, and above-ground biomass and grain yield of wheat based on the soil types and agroecology of the country. This review suggested that the response of the wheat crop to nitrogen fertilizer is not at the same rate as that of other nitrogen fertilizers.

Therefore, it is crucial to understand the nutritional status of the soil and plant nutrient uptake prior to applying fertilizer. In addition, different plant species and genotypes have different capacities for absorbing water, absorbing nutrients, and responding to stress. It concluded that the application of an appropriate amount of nitrogen fertilizer can be regarded as the main means to increase grain yield, improve the uptake of nitrogen and the utilization effectiveness of wheat, reduce farmer costs, and reduce environmental contamination.

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