OPEN ACCESS
Global Journal of Research in Agriculture & Life Sciences
ISSN: 2583-4576 (Online)
Volume 05 | Issue 03 | May-June | 2025
Journal homepage: https://gjrpublication.com/gjrals/
Research Article

Enhancing of Wheat Crop Productivity Through Using High Plant Density and Methods and Rats of Fertilizer Application

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DOI: 10.5281/zenodo.15359028 **Submission Date: 02 April 2025 | Published Date: 07 May 2025**

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Abstract

Ethiopia is the second largest wheat (Triticum aestivum L.) producer in sub-Saharan Africa, after South Africa. In recent decades, much of the improvement in wheat production has largely been driven by nutrient management and advances in crop genetics. The Ethiopian Institution of Agriculture Research Center concludes that the gap is due to limited wheat land expansion in the country's lowland agro-ecologies and low crop productivity under irrigation production. This review paper addresses to enhance the bread wheat productivity through using methods of fertilizer application; plant density and fertilizer rate. Although production is dominated by smallholder farmers (4.8 million, or about 32 percent of grain producers), and almost all wheat is produced under rain-fed conditions, Ethiopia is the largest wheat producer in sub-Saharan Africa. Ethiopia is one of the principal producers of wheat in East, Central, and Southern Africa. It is produced mainly in the southeast, northwest, and central parts of Ethiopia. A small amount is also produced in the rest of the south and north. Current wheat yields are roughly double the average wheat yields from 20 years ago, implying that more than half of the growth in production since 1996 can be attributed to yield growth. The importance of splitting nitrogen in three split doses (1/4th at sowing, ½ at tillering and the other 1/4th at booting) was also evidenced in the optimum yields and improving nitrogen recovery.

Keywords: *fertilizer rat, row spacing, bread wheat.*

1. INTRODUCTION

Agriculture is the backbone of the Ethiopian economy. The nutritional value of wheat is extremely important, as it takes an important place among the few crop species being extensively grown as staple food sources [36]. According to [16], wheat crops are more important in global trade than all other crops combined, and it has been a staple food for major civilizations for 8,000 years. It is also the most cultivated cereal crop in the world, and the quantity produced is greater than that of any other crop, feeding about 40 percent of the world's population as of January 2022. The majority of the Ethiopians are farmers, but they have not yet secured food at large. Abiotic and biotic factors constrain this. Therefore, it requires taking critical actions to solve it [18]. By promoting and implementing a sustainable agricultural management model, the use of chemical plant protection products and mineral fertilizers can be rationalized. The share of natural fertilizers and biological plant protection methods can also be increased. Various regions of the world experience soil contamination because of improper use of artificial fertilizers, calcium, and plant protection products [27]. Pesticides and artificial fertilizers have been reduced by almost half in winter wheat cultivation (down to almost none). Promoting and implementing the sustainable agriculture model result in the rational use of chemical plant protection products and mineral fertilizers [21].

Ethiopia is the second largest wheat (Triticum aestivum L.) producer in sub-Saharan Africa, after South Africa [15]. And according to the CSA's 2019 assessment, wheat ranks fourth after tef (Eragrostis tef), maize (Zea mays L.), and sorghum

(Sorghum bicolor L. Moench) in area coverage and total production. Notwithstanding the long history of wheat cultivation and its importance to Ethiopian agriculture, its average productivity is still very low at 2.76, 2.66, and 2.7 t ha−1 at the national, SNNPRS, and Kambata Tambaro zones, respectively [6]. In all cases, this is far below the world's average yield (3.52 t ha−1) reported by [33]. [4] Determined that wheat (Triticum aestivum, 2n = 6x = 42, AABBDD) is one of the most important food security crops in Ethiopia. During 2021/22, it is grown on a total of 2.1 million hectares (1.7 million ha under rain-fed conditions and 0.4 million ha under irrigated conditions), yielding 6.7 million tons of grain at an average productivity of 3.0 and 4.0 t/ha under rain-fed and irrigated conditions, respectively. Both bread and durum wheat is cultivated in Ethiopia. The tetraploid wheat (durum and emmer wheat, Triticum turgidum, 2n = 4x = 28, AABB) has been dominantly cultivated in Ethiopia for thousands of years, and there have been diverse collections of landraces stored in the Ethiopian national gene bank and other gene banks (Gatersleben, Germany, CIMMYT, ICARDA, USAID, etc.). Bread wheat (Triticum aestivum, 2n = 6x = 42, AABBDD), which accounts for 95 % of the global wheat production area, was introduced to Ethiopia in the early 1940s, and since the 1970s, it has become the dominant wheat type, covering more than 90 % of the total wheat production area in Ethiopia [5], [22]. In recent decades, much of the improvement in wheat production has largely been driven by nutrient management and advances in crop genetics [25]. In addition, other agronomic practices have long been investigated as a means of enhancing the productivity of food, forage, and energy crops [11].

1.2 Statements of the Problem

According to the [14] report, the low yield of wheat may be due to soil erosion, intensive crop cultivation, and inadequate application of N and P for a long time without considering soil fertility status and crop requirements, which were the major constraints in Ethiopia. In addition to this research, findings showed that acute crop cultivation, complete crop residue removal, and high nutrient depletion contribute to the low productivity of wheat. According to EIAR, and FAOSTAT reports, there is a gap between bread wheat production and demand levels in the country, which makes Ethiopia continually a net importer of about 1.5 million tons of wheat annually, draining 300-400 million USD, the national treasury [14]; [17]. The Ethiopian Institution of Agriculture Research Center concludes that the gap is due to limited wheat land expansion in the country's lowland agro-ecologies and low crop productivity under irrigation production (less than 4 t ha-1) that is (2.5 t ha-1) lower than the crop's achievable yield (6.5 t ha-1) asserted by Werner agricultural research center [12]. This review paper addresses to enhance the bread wheat productivity through using methods of fertilizer application; plant density and fertilizer rate.

1.3 Objective of the Study

1.3.1 General objective

The overall objective of this review is to enhance the bread wheat productivity through using various methods of fertilizer application; plant density and fertilizer rate

1.3.2 Specific objectives

To select the best bread wheat with its optimum fertilizer rate; application method and plant density for maximum productivity and

To evaluate the effect of different fertilizer rates on the growth, yield and yield components of bread wheat

2. LITERATURE REVIEW

2.1 Importance of wheat

In Ethiopia, bread wheat has become one of the most important strategic cereal crops due to its role in food security, import substitution, and the supply of raw materials for the agro-processing industry [12]; [19]. Wheat is an extremely important crop in terms of nutritional value, economic development, political advancement, and so on. Bran from flour milling is used in livestock feed, and the germ is a valuable addition to feed concentrate. Grains are fed to livestock either whole or coarsely ground. The wheat plant is also used as pasture feed before stem elongation, and this practice permits plant regeneration and grain harvest. According to [1] review, wheat is widely consumed in Ethiopia to meet consumer demand for bread and other food products. This indicated that there are several billion people worldwide who rely on wheat for a significant portion of their diet. Statistics for the total volume of wheat that is consumed directly by humans as opposed to feeding livestock in the United Kingdom indicate about one-third of the total production, or approximately 5.7 m metric tons per year, is milled for home production.

2.2 Wheat Production in Ethiopia

Agriculture is the backbone of the Ethiopian economy. The majority of the Ethiopians are farmers, but they have not yet secured food at large. Abiotic and biotic factors constrain this. Therefore, it requires taking critical actions to solve it. This review paper addresses the country's policymakers, academic workers, researchers, farmers, and other stakeholders to plan to solve the problems in the future. Furthermore, it is used for utilizing the country's agricultural productivity growth and political commitment and scrutinizes the necessity of mechanized farms at the national level [18]. According to [17] and the Office of the Gene Technology Regulator (OGTR) (2021), bread wheat is the most widely grown food crop in the world. And they noted that the global production of wheat in 2019 was estimated at 766 million metric tons. The major exporters of wheat are the Russian Federation, the United States, Canada, France, Ukraine, and Australia. In 2019, approximately 180 million metric tons of wheat were exported worldwide, with a value of $US 40 billion. In 2019, Australia exported 22.0 million metric tons with a value of $US4.7 billion [17].

Ethiopia is the primary wheat producer in Sub-Saharan Africa (SSA) owing to the suitable agro ecological conditions. Despite wheat's economic potential for food security, the actual yield under smallholder farmers' conditions is low due to various production constraints. Thus, the objectives of this study were to assess the present wheat production opportunities and constraints and identify farmer-preferred traits to guide variety design with stem rust resistance and economic traits in eastern Ethiopia. Data on production constraints and trait preferences were collected using structured questionnaires involving 144 wheat-producing farmers. Wheat rust (reported by 97.3 % of respondents), small land size (90.4 %), and a lack of improved varieties (75.6 %) were identified as the major constraints. About 41.7% of respondents in the West Hararghe and 27.8 % in the East Hararghe zones did not use crop protection strategies to control rust. To control rust diseases, farmers used cultural practices (18.8%), rust-resistant cultivars (13.2%), or a combination of these (10.4%). The essential farmer-preferred traits in a wheat variety were rust resistance, high yield potential, and good quality grain for bread making. Therefore, there is a need to breed new varieties with high grain yield and quality and durable rust resistance for sustainable wheat production in eastern Ethiopia [18].

Although production is dominated by smallholder farmers (4.8 million, or about 32 percent of grain producers), and almost all wheat is produced under rain-fed conditions, Ethiopia is the largest wheat producer in sub-Saharan Africa [3]. The country's total production during 2019/2020 crop growing season is 5.3 million tons on 1.8 million ha of land, accounting for approximately 18% of total cereal production with an average productivity of 2.97 t/ha [7]; [34]. The Amhara National Regional State is one of the major bread wheat-growing regions of the country, with a contribution of 27% to production. Its land coverage in the region during the 2019/2020 production year was 578,034.07 ha, with a total annual production of 1,611,784.14 tons and productivity of 2.88 t ha^{-1} [7]. The irrigation potential in the lowlands (<1500 m.a.s.l.) areas of the country have the intact potential for wheat production, which can make the country self-sufficient in wheat in a short period of time [12].

According to government reports, wheat imports could be significantly reduced by 2023, and Ethiopia eyes wheat self-sufficiency and export by 2025. Involvement of different stakeholders, including farmer unions, youth groups, commercial farmers, seed growers, millers, banks, and cooperatives, and the deployment of favorable policies to enable the availability and accessibility of inputs, extension services, transportation, mechanization, and marketing infrastructures are key to achieving the wheat revolution in Ethiopia [39]. [24] Conclude that despite the potential and growing trend of wheat production, the demand is steadily increasing and has yet to meet the country's annual demand. The demand for wheat is growing at an average rate of 9 percent per year, while local production is only growing at a rate of 7.8 percent. [26] Also reported that Ethiopia remains a net importer of wheat as a result of a gap between production and consumption levels. Ethiopia is one of the principal producers of wheat in East, Central, and Southern Africa. It is produced mainly in the southeast, northwest, and central parts of Ethiopia. A small amount is also produced in the rest of the south and north. Wheat is one of the major cereal crops in the Ethiopian highlands, which range between 6 and 16°N, 35 and 42°E, and from 1500 to 2800 m. At present, wheat is produced solely under rain-fed conditions [1].

According to the review by [1], the area coverage of bread wheat has substantially expanded, mainly by replacing unimproved, input-nonresponsive traditional cereal crops such as teff (Eragrostis teff), durum wheat (T. durum), and barley (Hordeum vulgare). According to Abbaye's 2021 review, Ethiopia has increased its wheat yield by approximately 3.7 percent per year over the last two decades. Current wheat yields are roughly double the average wheat yields from 20 years ago, implying that more than half of the growth in production since 1996 can be attributed to yield growth. The rate of growth has been especially high in recent years: since 2005, the yield has increased by more than 5.2 percent per year. Yet, compared to the yields accomplished by other major producers in Africa (for example, Egypt, South Africa, and Kenya), Ethiopian wheat yields are low, indicating a considerable potential for improvement. Various constraints combine to explain the wheat yield gaps in Ethiopia. The use of modern production-enhancing inputs, such as fertilizers and improved seeds, among wheat farmers in Ethiopia are reportedly low [1].

According to the [6] assessment result, wheat (*Triticum aestivum*, 2n = 6x = 42, AABBDD) is one of the most important food security crops in Ethiopia. During 2021/22, it is grown on a total of 2.1 million hectares (1.7 million ha under rain-fed conditions and 0.4 million ha under irrigated conditions), yielding 6.7 million tons of grain at an average productivity of 3.0 and 4.0 t/ha under rain-fed and irrigated conditions, respectively. The rain-fed wheat production is dominantly carried out during the main rainy season in Ethiopia (June to October) in the highlands of the country, while irrigated wheat production is carried out from November to April in the lowlands of Ethiopia along the Awash, Wabe Shebele, and Omo River basins [39].

2.3 Enhancing of wheat crop productivity through using high plant density

The optimal seeding rate and fertilizer rate combination are critical in achieving an economic yield. Thus, the proper seeding rate and addition of adequate nutrients such as N, P, and S to the soil are important to increase wheat yield, either for consumption or industrial purposes. As a result, better seeding and fertilizer rate interactions are the most important factors in wheat production [36]. Results from the analysis of variance indicated that both the main and their interaction effect of seed rate and row spacing were highly significant ($P< 0.01$) on thousand seed weight at Metema. Highest thousand seed weight (27.3 g) was obtained from 80 kg ha^{-1} of seed rate and 30cm of row spacing while the lowest thousand seed weight (17.1 g) was found at 120 kg ha^{-1} and 25 cm of seed rate and row spacing, respectively. The highest thousand grain weight at widest spacing might be due to efficient utilization of water, nutrients and light with minimal inter rows competition. On the other hand, at highest density competition would increase and little photosynthesis would be available to grain filling and finally thousand seed weight would reduce as result of insufficient photosynthesis during grain filling stage in densely populated crops [13].

Mean Plant height and thousand seed weight of weight was significantly affected by seed rates, with higher mean plant height of (99.74 cm) and 1000 seed weight (50.67 g) was obtained from planting of 150 kg ha^{-1} seed rate of wheat [32] However, [2] conclude that as seeding rate increased from the lowest (100 kg/ ha) to the highest (175 kg/ha), the height of the plant correspondingly increased. The main effects of seed rate and inter row spacing as well as their interactions did not affect plant height significantly. Higher seeding rate caused change in plant height and stem thickness because of the lower light penetration in to the plants canopy bed and more inter specific competition to more absorption light [20].

The mean number of tillers per plant of wheat was also significantly influenced by seed rate. Number of tiller plant of wheat was decreasing with increasing of seed rate. Significantly higher number of tillers plant wheat was recorded from the lower seed rate of 125 kg ha^{-1} [32]. The mean number of tiller plant of wheat was indicated significantly increasing with increasing of row spacing of wheat. Wider row spacing (20 and 25 cm) were produced significantly higher thousand seed weight than narrower row spacing [32]. Crop yields are generally dependent upon many yield contributing agents. Effects of seeding rates and row spacing were none significant on spike length. Even though it is none significant, the lower seed rate and narrow row spacing, the spike length was lower compared to higher seed rate and wider rows. This might be due to more free space between plants at the lower seed rates and less intra-plant competition for available resources that resulted in higher spike length [2]. [20] Reported that the main effects of seed rate and inter row spacing as well as their interactions did not affect plant height significantly. However, the lower seeding rate and wider row spacing the spike length was higher compared to higher seeding rate and the higher seed rate.

[2] Reported that the number of seeds per spike was significantly ($p<0.05$) influenced by seeding rate in 2018. Maximum number of seeds per spike (50.13) was obtained due to seed rate of 100 kg/ha and minimum number of seeds per spike (40.85) obtained from the seeding rate of 175 kg/h a. Row spacing and its interaction with seed rate did not affected number of seeds per plant. There was no significant difference observed among seeding rates of 100, 125 and 150 kg ha^{-1} in spike length. At the lower seeding rate of 100 kg ha^{-1}, the spike length was higher compared to higher seeding rate of 175 kg ha^{-1}. This might be due to more free space between plants at the lower seed rates and less intra-plant competition for available resources that resulted in higher spike length. Seeding rates of wheat was significantly ($P<0.05$) affected the mean grain yield, dry biomass, harvest index, plant height, tiller number per plant and 1000 seed weight of wheat. Significantly higher mean grain yields (4814 kg ha^{-1}) of wheat during 2012-2014 were obtained with planting of 150 kg ha^{-1} seed rate wheat followed by 4186 kg ha^{-1}) mean grain yield with planting of 175 kg ha^{-1} seeding rate but not statistically at par from the mean yield obtained with lowest seeding rate (125 kg ha^{-1}). Significantly mean grain yield advantage of 34.38 and 14.11 % were obtained from planting of 150 kg ha^{-1} seeding rate as compared to use of 175 and 125 kg ha^{-1} seeding rate [32].

Seeding rate of 150 and 175 kg ha^{-1} resulted in increasing yield by 45.39 % and 38.19 %, over the lowest seeding rate of 100 kg ha^{-1}, respectively, the increased seeding rate from 125 kg ha^{-1} to 150 kg ha^{-1}produced grain yield which was significantly increased by 20.06 %. The main effect of seed rate had significant effect ($p < 0.05$) on grain yield. The highest grain yield (4568 kg/ha) was obtained at the seed rate of 150 kg/ha. The maximum grain yield obtained from the use of higher seed rate might be due to high density of plants in rows and increased number of spikes per rows as a result number of grains and increased spike number in rows. Due to seed rate of 150 kg/ha, 229 kg and 415 kg yield advantage obtained compared to 100 kg/ha and 125 kg/ha seed respectively [2].

The combine analysis of variance revealed that the main effect of seed rate was highly significant ($P<0.01$) on biomass yield and row spacing was not significance ($P<0.05$) different on biomass yield while their interaction not significant. The highest biomass yield (8568 kg ha^{-1}) was obtained at 120 kg ha^{-1} seed rate. However; this was statistically in parity with seed rate of 100 kg ha^{-1}. While the lowest biomass yield (5710 kg ha^{-1}) was obtained at 60 kg ha^{-1} seed rate. In general, biomasses yield increase with the increasing seed rate. There was an increase of 36% in biomass yield with the application of 120 kg seed rate ha^{-1} over 60 kg seed rate ha^{-1}. Seed rate (80 kg ha^{-1}) attained higher plant height, thousand seed weight and produced more tillers which promoted vegetative growth as well as development of the plants than their lower rates. The total dry matter per unit area was increased with an increase in spacing. This, in other way, implied that higher planting density within limit might produce more total dry matter per unit area which agrees with the results of this study [13].

2.4 Enhancing of wheat crop productivity through using methods fertilizer application

Generally, significantly maximum plant height was recorded in the application of N at early and tillering stage of the crop than at a later stage of the crop in all locations. The possible explanation of the positive effect of split N application compared to single N application at later growth stages is gaseous losses from applied topdressing [9]. Precision-oriented technological change in the agricultural sector is leading to better management practices that make all agricultural technological operations, from tillage to harvesting, more precise, resulting in reduced costs, increased profits, and environmental sustainability [28]; [31]. Scientists have found that by applying variable-rate fertilization, grain yield does not decrease when the fertilization rate is reduced [37]; [8].

The main effect of NPS fertilizer, as well as the interaction effect of NPS with seed rates, had a highly significant (P > 0.01) effect on the number of productive tillers. A higher number of productive tillers (631.7 m2) was observed when an NPS fertilizer rate of 150 kg NPS ha^{-1} was combined with a seeding rate of 150 kg ha^{-1}, and a statistically lower number (485 m2) was observed when a seeding rate of 100 kg ha^{-1} was combined with 0 kg NPS. Productive tillers are the most important because of their contribution to the final yield. The NPS nutrients increased the number of productive tillers significantly. This might be due to N feed as NPS and also a top-dressing of N fertilizer applied at the time of tillering initiations [35]. [36] Showed that the highest number of grains per spike (48.3) was recorded from an NPSB fertilizer rate of 150 kg ha^{-1}. The maximum number of grains per spike (40.67) was recorded for both 250 kg NPS ha^{-1} fertilizer rate with a seeding rate of 100 kg ha^{-1} and 200 kg NPS ha^{-1} with a seeding rate of 150 kg ha^{-1}. While the minimum number of grains per spike (25) was recorded from 0 kg NPS with a seeding rate of 150 kg $ha^{-1,}$ the increased number of grains per spike could be due to optimum crop stand and better nutrition from NPS fertilizer. Better nutrition enhanced the source's capacity to better fill the sink [35]. Balanced plant nutrition is one of the most important factors that increase plant production. Balanced supplementation of NPS nutrition is one of the greatest production inputs for crops in highland and lowland areas. Maximum grain yield might be attributed to improvements in several productive tillers, spike length, kernels per spike, and thousand kernel weight. It could also be due to the top-dressing of N fertilizer applied at the time of tillering initiations, where bread wheat needs a high amount of N (60-70%) at this stage for grain production, which significantly increased grain yield [35]. The balanced supply of NPS nutrients leads to more vegetative growth and more dry matter accumulation, which are directly related to an increase in straw yield [35].

2.5 Enhancing of wheat crop productivity through using rats of fertilizer application

Proper application of the recommended fertilizer rate is important to obtain the required production and marketable supply. However, farmers in the study area apply varying fertilizer rate, which is below the blanket recommendation rate given by Sinana Agricultural Research Centre. The recommendation rate given by Sinana Agricultural Research Centre is to apply 100 kg of DAP and 50kg of UREA per hectare. The survey result indicated that 73.13 % the sample respondents used UREA and DAP fertilizer on their wheat field [38].

The application of a large quantity of nitrogen (a minimum of 240 kg N ha^{-1}) in three split doses (T5) was required to obtain optimum wheat yield, which is about 2.5- fold higher than the national average yield of the crop in Ethiopia. The soil requires application of as much as 240 kg N ha^{-1} to produce about 6 tons of wheat per hectare which implies that the soil is productive unless the nitrogen uptake efficiency of the crop possibly is reduced as a result of its characteristic waterlogging condition. The importance of splitting nitrogen in three split doses (1/4th at sowing, ½ at tillering and the other 1/4th at booting) was also evidenced in the optimum yields and improving nitrogen recovery. Nitrogen fertilizer led to a general decrease of nitrogen use efficiency traits in both growing years.

The application of a large quantity of nitrogen (a minimum of 240 kg N ha^{-1}) in three split doses (T5) was required to obtain an optimum wheat yield, which is about 2.5 times higher than the national average yield of the crop in Ethiopia. The soil requires the application of as much as 240 kg N ha-1 to produce about 6 tons of wheat per hectare, which implies that the soil is productive unless the nitrogen uptake efficiency of the crop is possibly reduced as a result of its characteristic waterlogging condition. The importance of splitting nitrogen into three split doses (1/4th at sowing, ½ at tillering, and the other 1/4th at booting) was also evidenced in the optimum yields and improved nitrogen recovery. Nitrogen fertilizer led to a general decrease in nitrogen efficiency traits in both growing years.

Increasing the rates of blended NPSB fertilizer increased the number of kernels produced per spike. Seed rate 125 kg ha^{-1} produced the maximum number of kernels per spike (41.68), whereas the minimum number of kernels per spike (36.77) was produced for seed rate 200 kg ha^{-1}. The highest number of kernels (46.45) was produced at the highest rate of NPSB fertilizers (150 kg ha^{-1} NPSB), whereas the minimum number of kernels per spike (32.03) was produced at a nil NPSB rate. The number of kernels per spike was enhanced by NPSB, which might be because P is essential in the development of grains [30]. Accordingly, [30] conclude that the result may be because boron plays a vital role in the grain setting of wheat. Therefore, the supply of boron-containing fertilizer helps in grain filling, and ultimately sterility is reduced and the number of grains per spike increases. These also showed the synergistic effect of the fertilizers, resulting in increased kernel count per spike and grain production.

The combined application of N and K fertilizers at increasing rates relatively prolonged maturity by two weeks as compared to non-fertilized plots. In comparison, increasing N rates at all levels of K rates extend the days to physiological maturity. This might suggest that N fertilization is associated with extended vegetative growth. However, the combined application of N and K fertilization regulated the extreme cases maturity of wheat (i.e. too early and too late [29]. [29] Also said that this could probably be due to the major role of N towards cell division, elongation, and enhancing the vegetative growth of plants, and the role of K in promoting vigorous plant growth through efficient photosynthesis. When N and K fertilizers are applied together enhance vigorous vegetative growth and resulted in increasing plant height of wheat. [35] Also conclude that increasing the rate of NPS at higher levels increased spike length. Increase in spike length might be due to adequate NPS fertilizer applications which resulted in better length of the spike.

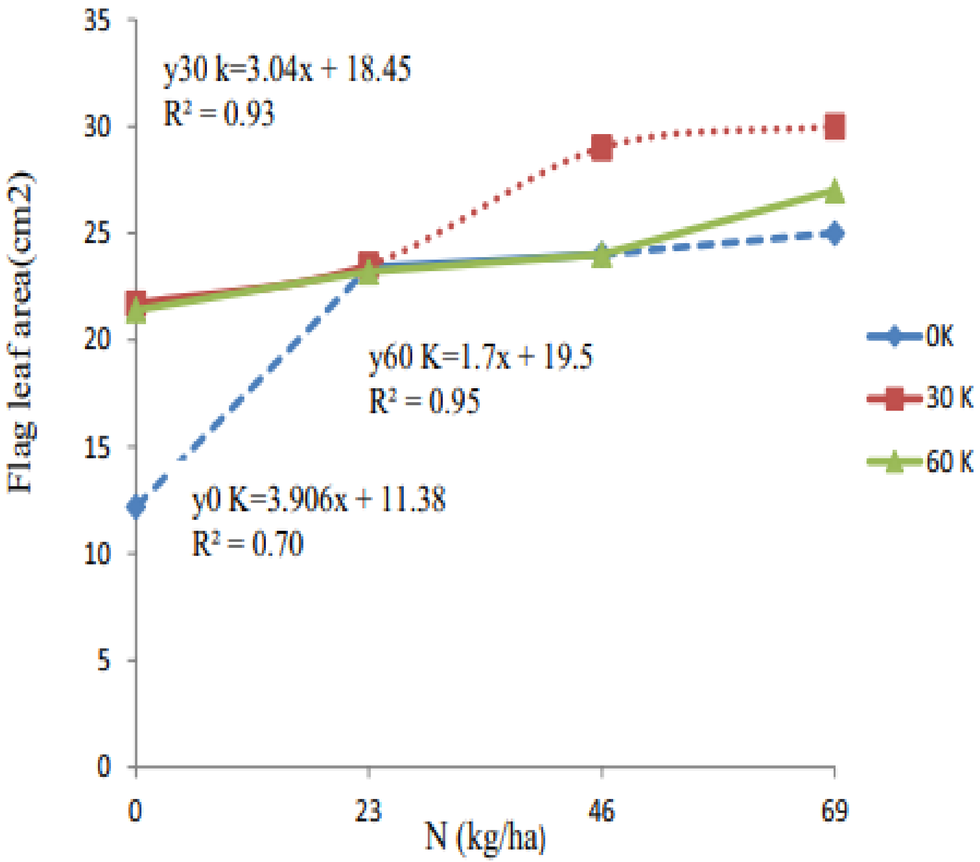

Figure 1 Relationship between interactions effects of N x K and fag leaf area

Source: Temesgen *et al.*, (2021).

The study showed wheat grain yield and protein content was highly influenced by the environment and indirectly correlated with each other as affected by N time of applications. The grain yield was increased by 31%, 14 % and 18 %, respectively when N was applied with DAP at sowing over the blanket recommendations. But the grain protein content decreased as the split application increased. Thus, depending on the purpose of the producers, it can concluded that application of ½ urea at 50 % emergence + ½ urea at tillering with the application of N with DAP at sowing gave maximum wheat grain yield, while optimum grain protein content was obtained when N was applied after the crop is emerged and would be used in most dominant wheat producing areas of northwestern Ethiopia [9]. According to [23] both S and N have the potential to enhance wheat growth, yield attributes, and protein contents. For the achievement of better nitrogen and sulfur uptake, the addition of 120N + 60S is a balance application combination for wheat growers. The addition of 120N + 60S has significant potential for improvement in wheat grain yield. Growers are suggested to apply 120N + 60S for better production of wheat.

[35] Reported that the seeding rates and NPS nutritional levels under different environmental conditions would be very useful in planning of our seeding system and NPS rates for increasing of productions in the specific study area. Seed rate did not bring significant effect on most of the yield and yield components at all locations. However, its interaction with seeding rate and fertilizer rates attributes had significant effect on yield component parameters. When we use the highest N rate of 184 kg ha^{-1} the highest plant heights were recorded, while the shortest plant height was recorded on plots without N application. But N fertilizer application beyond optimum does not have significant effect on spike length of wheat [10].

The effect of fertilizer also showed that the highest number of kernels per spike (48.3) was recorded from NPSB fertilizer rate of 150 kg ha^{-1}. Such response can be attributed to the adequate nitrogen availability which might facilitate the tillering ability of the plants, resulting in a greater spike population [36]. And [36] understood that the highest thousand kernels weight (43.8 g) was recorded from NPSB fertilizer rate of 150 kg ha^{-1} while the lowest thousand kernels weight (38.1 g) was obtained with no fertilizer application. This may be due to the provision of balanced nutrients application have enhanced accumulation of assimilate in the grains and thus resulting in heavier grains of wheat. This could also be due to adequate and better nutrition of the plants resulted in good grain filling and development of better seed size. The increase in grain yield at NP rate might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to the synergetic effects of both nutrients which enhanced yield components and yield [36].

Cording to [30] grain yield as affected by interaction of N by K rates ranged from 1041 to 4392 kg ha^{-1}. All fertilized plots had higher grain yield as compared to plots without fertilization. Grain yield tended to increase with increasing N rate up to 46 kg ha^{-1} and then declined above that rate of N across all levels of K rates. Regarding the effect K rates, higher grain yield was recorded at K rate of 30 kg ha^{-1} and then grain yield declined above that rate of K across all levels of N rates. The highest grain yield (4392 kg ha^{-1}) was achieved from combination of 46 kg N ha^{-1} with 30 kg K ha^{-1}. [30] prominent that generally optimization of N and K fertilizer combination resulted in positive effect for the parameters correlated with grain yield suggesting that their increase led to increment in grain yield to a certain optimum level.

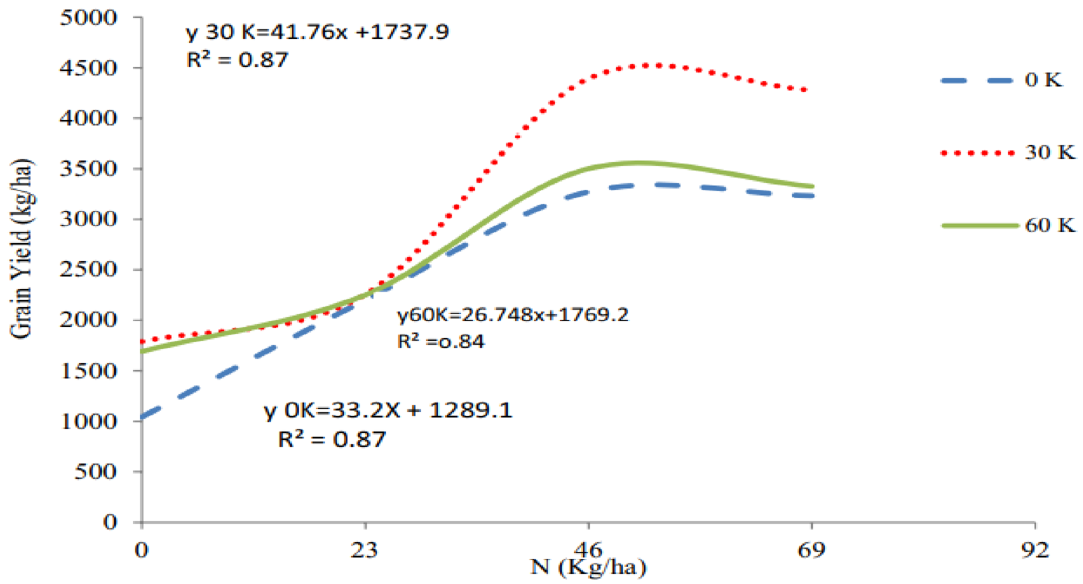

Figure 2 Relationship between interaction effects of N x K on grain yield

Source: Temesgen *et al.*, (2021).

2.6 Constraint of wheat production in Ethiopia

Ethiopian agriculture is mostly subsistence in nature and hence less capital demanding. On the other side, there are some commercial farms run by entrepreneurs with substantial investments. The land ownership policy is one of the key causes for Ethiopia's lack of commercial agriculture [39]. Furthermore, Ethiopians, particularly agricultural professionals, should learn from the past experiences of their colleagues who pioneered private farms and the current private banking sector, and form joint ventures in establishing commercial farming, seed companies, milling industries, and bakeries by involving millions of shareholders to mobilize resources. Such practical measures will enable the agricultural industry to be modernized, increasing production, creating employment and income, substituting imports, and so on. One of the most pressing issues confronting Ethiopia at the moment is the production of enough food to feed the country's rapidly growing population. Getting more agricultural land-dwellers into farming is not possible in closely inhabited regions. Improved agricultural productivity requires higher yields per unit of land area, which increases the market demand for improving the production and productivity of bread wheat to increase the market supply at a reasonable market price. Previous research has shown that selecting varieties that are related to the specified population and used by farmers may be a viable option for improving bread wheat markets [1].

Fertilizers are imported, and hence the cost increases with energy prices and global demands. Furthermore, transportation accessibility and cost, as well as credit availability, have an impact on fertilizer distribution to farmers. Water availability and installation costs for irrigation schemes are limiting factors for expanding wheat production in irrigated environments [39]. The interaction between the bread wheat varieties' seed size and plant population levels showed that the most economical and profitable grain yield of 4100 and 4339 kg ha^{-1} was produced at a seed rate of 250 and 300 plants m^{-2} for the variety Hidassie, with large seed size, respectively [1]. According to [16] and [26], understanding and prioritizing the main production constraints are important before embarking on the expansion of local wheat production. Wheat production in Ethiopia suffers from diseases (rusts, septoria, fusarium, etc.), soil acidity, declining soil fertility, terminal moisture stress, heat, mono-cropping, pre-harvest sprouting, and climate change. Furthermore, growing populations, increased rural-urban migration, low public and private investments, weak extension systems, inappropriate agricultural policies, and yield gaps because of low adoption of new technologies remain major challenges.

Most developed-world wheat-growing countries use a one-time application of general fungicides prior to the presence of any diseases, and it has been reported that this practice has significantly increased yield. Similarly, Ethiopian wheat farmers should spray general fungicide (Propiconazole at the rate of 0.5 L/ha) to protect their wheat crop against diseases, lower the inoculum build, and slow down mutation rates of pathogens [39]. To balance these challenges and achieve wheat self-sufficiency and export in Ethiopia, a two-pronged approach is required: (i) closing the yield gap in traditional rain-fed highland wheat growing areas by developing and scaling climate-buoyant high-yielding varieties and associated integrated crop management practices; and (ii) expanding wheat production in the new limits of irrigated lowland areas by developing and scaling high-yielding heat-tolerant varieties and associated integrated crop management practices.

3. SUMMERY CONCLUSIONS

The nutritional value of wheat is extremely important, as it takes an important place among the few crop species being extensively grown as staple food sources. The majority of the Ethiopians are farmers, but they have not yet secured food at large. Abiotic and biotic factors constrain this. Therefore, it requires taking critical actions to solve it. The low yield of wheat may be due to soil erosion, intensive crop cultivation, and inadequate application of N and P for a long time without considering soil fertility status and crop requirements, which were the major constraints in Ethiopia. In addition to this research, findings showed that acute crop cultivation, complete crop residue removal, and high nutrient depletion contribute to the low productivity of wheat. Wheat is an extremely important crop in terms of nutritional value, economic development, political advancement, and so on. The optimal seeding rate and fertilizer rate combination are critical in achieving an economic yield. Thus, the proper seeding rate and addition of adequate nutrients such as N, P, and S to the soil are important to increase wheat yield, either for consumption or industrial purposes. Seeding rate of 150 and 175 kg ha^{-1} resulted in increasing yield by 45.39 % and 38.19 %, over the lowest seeding rate of 100 kg ha^{-1}, respectively, the increased seeding rate from 125 kg ha^{-1} to 150 kg ha^{-1}produced grain yield which was significantly increased by 20.06 %. Generally, significantly maximum plant height was recorded in the application of N at early and tillering stage of the crop than at a later stage of the crop in all locations. The possible explanation of the positive effect of split N application compared to single N application at later growth stages is gaseous losses from applied topdressing. Proper application of the recommended fertilizer rate is important to obtain the required production and marketable supply. However, farmers in the study area apply varying fertilizer rate, which is below the blanket recommendation rate given by Sinana Agricultural Research Centre. Furthermore, Ethiopians, particularly agricultural professionals, should learn from the past experiences of their colleagues who pioneered private farms and the current private banking sector, and form joint ventures in establishing commercial farming, seed companies, milling industries, and bakeries by involving millions of shareholders to mobilize resources.

ABBREVIATIONS

CSA	Central Statistics Agency
FAOSTAT	Food and Agriculture Organization of the United Nations
EIAR	Ethiopian Institute of Agricultural Research
OGTR	Office of the Gene Technology Regulator
SSA	Sub-Saharan Africa
USDA	United States Department of Agricultural

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CITATION

Mandefro G. H., Shiwafera, M., & Belayneh S. (2025). Enhancing of Wheat Crop Productivity Through Using High Plant Density and Methods and Rats of Fertilizer Application. In Global Journal of Research in Agriculture & Life Sciences (Vol. 5, Number 3, pp. 14–23).
https://doi.org/10.5281/zenodo.15359028