
The Synergy of Macro and Micro-Nutrients for Improving Durum Wheat Productivity in Ethiopia: A Review

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Abstract: Durum wheat (*Triticum turgidum* L. Var. Durum) is an indigenous predominant tetraploid wheat species and well grown in Ethiopia. It is good amount and a source of protein, fibers and minerals. In Ethiopia, more than 42 durum wheat varieties were released for production since 1950s. However, the national average yield of the crop is not more than 2.6 tons/hectare, which is far the potential yield of crop 6-8 tone/hectare. Conversely, the demand for durum wheat has steadily increased in country the last decades, particularly due to the emergence of many food processing industries. These calls for increasing yield and improving of grain quality traits are a major task in Ethiopia. The review was emphasized research achievements, limitation, gaps, and future outlook on macro and micro nutrients uses and their synergy, where durum wheat is the principal crop cultivation. It has been indicated growth, productivity and grain quality are largely improved both by macro and micro nutrients together with elite cultivars of the durum wheat. The maximum crop growth rate, relative growth rate, leaf area index, yield components, yield, protein contents, wet gluten, dry gluten, hectoliter weight, and gluten index were improved by combined application of macro nutrients (N, P₂O₅, S) and micronutrients such as (Boron). We, therefore, suggested that, research on the macro and micronutrient strategies are most important for the durum wheat production and productivity, while the soil physico-chemicals analysis stills deserve outmost attention.

Keywords: Nitrogen, Phosphorus, Sulfur, Boron, Grain Quality

1. Introduction

More than 80% Ethiopian economy depend on agricultures and it plays an important role. Over 35% contributes for the annual GDP, about 80% to the export earnings and it employs over 75% of the population CSA, [1]. Of the agricultural GDP, the contribution from crop production takes the lion's share that is about 70% or more. Within the crop production system, the share of cereals in areas and production is about 80%, and 85%, respectively CSA, [2]. Among the cereals crop, tef, maize and wheat have a share of 60% of the fertilizer inputs, about 55% of the land areas and 60% of the annual production of cereals CSA, [2].

Both bread and durum wheat crops are cultivated and it is food cereal crops in Ethiopia. Since 2005, Ethiopia has been the largest wheat producer in sub Sharan Africa FAOSTAT, [3]. The crops are well grown about 1.6-1.8 million ha annually and with an estimated 5 million farming household's CSA, [4]. In Ethiopia, the crops are used for both a food source

and straw for animal feed source and income generation for the small-holders farmers. The demand of durum wheat in the country is growing rapidly because of shifting dietary patterns linked to urbanization that are mirrored across other eastern and southern African countries Mason, L., [5].

Before the introduction of improved bread wheat varieties, durum wheat was the dominant wheat crop produced in Ethiopia. Until 1980s, of the wheat cultivated land, 60-70% land was covered by durum wheat and the remaining 30-40% was covered by bread wheat (*Triticum aestivum*). However, the introduction of improved bread wheat from international breeding programs (CIMMITY) into Ethiopia and their wide adaptation with satisfactory yield potential, farmer given less attentions for durum wheat cultivation even though the crop is an important. Currently, about 80% of the arable land devoted for bread wheat Nagassa, R. et al. [6], implying that 20% devoted to durum wheat.

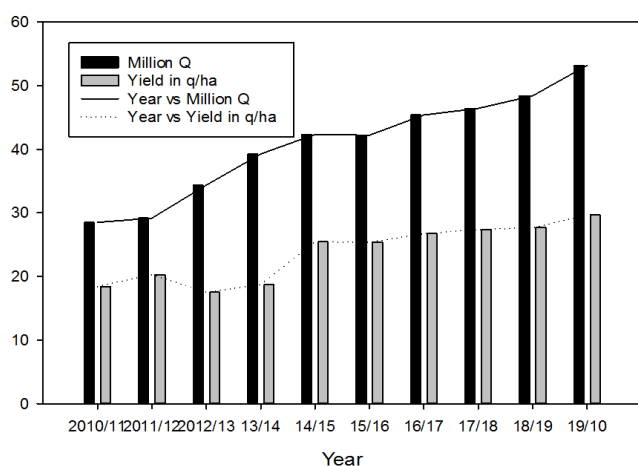


Figure 1. Wheat production status 2010 to 2020 in Ethiopia.

Ethiopia is also known as the indigenous predominant and a center of diversity for tetraploid including durum wheat Kabija, H. et al. [7]; Harlan, J. et al. [8] Vavilov, N. et al. [9], although recent reported by Kabija, H. et al. [7] indicated that Ethiopia might be represent a second center of origin for durum wheat. In Ethiopia, more than 42 durum wheat varieties were released for the production since 1950s. However, the national average yield of durum wheat was 2.6 ton/ha CSA, [2], which is huge yield gap of 6-5 tone/hectare. Conversely, the demand of durum wheat was increased since 2000 in Ethiopia, particularly due to the emergence of many food processing industries Mitchell, D. et al. [10]. The rapid projected increases population 2.2 million peoples by 2050 will lead to higher demand of agricultural products Valin, H. [11]. Nevertheless, the domestic durum wheat production has been insufficient the domestic demands, resulting the country is imports around 50-80% of total wheat imports Benson, P and Voller, P., [12]; Tubiello, F., [13].

The depletion of soil nutrients, because of a continuous monocrop cultivation, low chemical fertilizer use and low adoption the use of organic matter application cumulatively decrease wheat productivity Kidane, G., [14]. In addition, for the last five decades, Ethiopian agriculture depended solely inorganic fertilizer namely urea and diammonium phosphate (DAP) which are only a source of N and P although most Ethiopian arable lands lack other macro- and micro-nutrients EthioSIS, [15]. This may lead to low soil fertility, resulting reduce nutrient utilization efficiency and presence of low nutrient availability consequently decreases crop productivity Wassie, H. and Shiferaw, B., [16]. According to the national soil data base, some of the micro-nutrients such as zinc, boron and copper are depleted from the arable lands of the country EthioSIS, [15]. Elsewhere, research finding indicated that the application of compound nutrients had been playing promising rolls for crop growth and development, which producing in quantity and quality of the agricultural product Natajara, T. et al. [17].

According to Chaudry, E. et al. [18] reported, application of micronutrients such as Zn, Fe, B combined application macro-nutrient played a positively improved wheat yield

compared to without the application of micronutrient combination with each other. Moreover, Mandal, A. et al. [19] reported micronutrient were also positive interaction with physiological stages of wheat growth. It is therefore crucial to address issues of nutrient and use efficiency and economic feasibility of nutrient application to enhance durum wheat productivity and grain (nutritional) quality, considering different management scenarios in a cohesive and dynamic manner.

So far, many research achievements have been made and several soil, climate and crop rotation specific research were addressed to determine the nutrient requirements of durum wheat crop. Nevertheless, most of the previous finding had been given less attention to micronutrients and the synergy of the two (Macro and micro nutrients). In addition, the research result have not been adequately summarized and organized in usable manner. The current review therefore, aims at reviewing the past research achievements, limitation and research gap and put the future outlook for sustainable production of durum wheat system.

2. Importance of Durum Wheat in Ethiopia

The durum wheat grain is mainly required for the manufacturing of pasta products (macaroni, spaghetti and semolina), it also utilized for a variety of dishes Mengistu, A. et al. [20]. Besides the grain, wheat straw is commonly used for animals feed, and roof tacking material. With the current privatization policy and immersing of past processing industry in the country Eshete, M. et al. [21], there is an increasing the demand of durum wheat grains for the raw materials of the processors. However, this huge demand of the grain is largely met through imports from other countries Gebreselassie, M. et al. [22].

3. Durum Wheat Production Constraints in Ethiopia

The major yield limiting factors of durum wheat production include abiotic and biotic factors Tanner, D. et al. [23]. The crop management practices are not fully tailored by agro-ecology, taking into account soil types, soil nutrient information, weather patterns, planting time, desired yields and pest and disease prevalence. The application rates and types of fertilizer and seeds follow more of blanket recommendation and are not sufficiently targeted to specific soil and agro-ecological variations Bekele, G. and Tanner, G., [24]. Moreover, they are not frequently updated in response to the existing prevailing condition. This prevents farmers from realizing the optimum yield they could otherwise achieve. Although strides have been made regarding soil test based fertilizer recommendations just recently, there is tremendous work yet to be done to scale out these recommendations to wider geographies ATA, [25].

4. The Power of Macro and Micro Nutrients for Crop Production

Plants required in a big quantity known as micro-nutrients consists of nitrogen (N), phosphorus (P), potassium (K), sulfur (S), magnesium (Mg) and calcium (Ca), that are used in big amounts, and big portions should be implemented if the soil is poor in a single or greater of them FAO, [26]. The micro-nutrients or hint factors are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl) and boron (B) FAO, [26]. They are component and parcel of the important thing materials in plant production and are similar with the nutrients in human nutrition. Being taken up in minute amounts, their variety of most useful deliver may be very small ATA, [25]. Their plant availability relies upon on the whole at the soil reaction.

4.1. Nitrogen

Nitrogen is the most important and required crop nutrient for the growth of a plant and in increasing the yield of the crop. The use of proper amount of nitrogen nutrient is considered key to obtain increased yield. In general, availability of adequate amount of nitrogen in the farm and crops are required by large, because it is one of the avital nutrients of crop production Nadeem, M. et al. [27]. Several studies showed that, nitrogen is an important plant nutrient for the formation of chlorophylls, which is the most important and associated with photosynthetic process Nursuaidah, H. et al. [28]. It makes up 1 to 4% of dry matter of the plant. Since nitrogen is present in so many essential compounds, growth and development of crop without application of nitrogen is slow growth and development.

Inorganic N exists in the form of NH_4^+ , NO_3^- , NO_2 , NO and the elemental nitrogen (N_2), while the organic forms include protein, amino acids, amino sugars and other complexes. The NH_4^+ , NO_3^- and NO_2 are produced from aerobic decomposition of organic matter or addition of fertilizers to the soil. A deficiency of N limits cell division and expansion, chloroplast development, chlorophyll concentration, and enzyme activity. Nitrogen deficiency symptoms include general stunting and yellowing, particularly of the older plant parts. In wheat, N deficiency mainly affects: leaf expansion (leaf area = light interception) and nitrogen concentration (chlorophyll concentration = radiation use efficiency) Ortiz –Monasterio, J. et al. [29].

4.2. Phosphorus

Phosphorus (P) is classified as the second most important element next to nitrogen for crop production. Phosphorus is crucial and involved in many physiological and biological processes of plants to complete their crop life cycle Tisdale, S. et al. [30]. It is a component of adenosine di-phosphate (ADP) and adenosine tri-phosphate (ATP). Adenosine tri-phosphate, synthesized from ADP through respiration, contains a high energy phosphate group that drives most biochemical processes requiring energy. It is also further

mentioned that the uptake of some nutrients and their transport within the plant as well as the synthesis of new molecules, are energy using processes that ATP helps to implement. Without adequate amount and application method of P, a plant cannot reach its maximum yield potential. Well development of crop root by with adequate supply of P fertilization in cereals as well as legume crops. Moreover, phosphorus plays strengthens of culm in plants and hence prevents lodging Fageria, N., [31].

The availability of soil P is affected by soil reaction, type, amount and forms of P as well as other soil factors. Nemours finding revealed that, sandy soils with low in humus have low available phosphorus Tisdale, S. et al. [30]. It is also stated that soils which are prone to sturdy phosphate fixation and adsorption to sesqui-oxides and clay minerals frequently require extraordinarily high phosphate fertilizer application in order to alleviate the results of fixation. In these strongly phosphate fixing soils, pH correction is also advocated due to the fact that phosphate adsorption is especially high at low pH levels.

4.3. Sulfur

Sulfur (S) is also categorized in macro-nutrients and it is the third most important plant nutrient and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis Ali, R. et al. [32]. The most important rolls of sulfur are building block of protein and a key ingredient in the chlorophyll formation of the crop Duke, S. and Reisenauer, H., [33]. It is also a potential rolls for improving protein content of the grain, synthesis of S containing amino acids such as cystine, cysteine and methionine Zhao, F. et al. [34]. Sulfur, its deficiency results in stunted growth, reduced plant height, tillers numbers per plant, spikelet per spike and delayed maturity of the crop, less resistance under stress conditions Doberman, A. and Fairhurst, T., [35]. Eriksen, J. et al. [36] provide a useful explanation of S mobility in barley and how S mobility interacts with N nutrition.

4.4. Boron

Boron is an essential micro-nutrient required by the plant for proper growth and development, and its deficiency would have various adverse effects on the plants, such as yellowing of the leaf tips, chlorosis and necrotic spots, stunted growth, and inhibition of the length and length of the buds leaves root shoots green-grey spots on fruits Miwa, K. et al. [37]. Recent evidence has shown that boron is the only element and has been shown to be beneficial for proper plant growth and development only when absorbed and stored in appropriate amounts. Not only does boron play an incredible role in the biosynthesis and lignification of cell walls, but it is also instrumental in a variety of physiological and biological processes such as tissue differentiation, vegetative growth, phenol metabolism, cell and membrane integrity Durgesh, K. et al. [38]. Apart from that, boron bioavailability is also required for nitrogen fixation and nitrate assimilation Beato, V. et al. [39]; Reguera, M. et al. [40], oxidative stress Pfeffer,

H. et al. [41] and root development Martin-Rejano, E., [42].

5. The Role of Nutrient Management on the Crop Growth

Crop growth analysis, one of the basic approaches' to the analysis of yield influencing factors and plant development as net photosynthetic accumulation is naturally integrated over time. Growth analysis is mostly used by plant physiologist and agronomists. Achieving higher growth attributes such as leaf area index, crop growth rate, relative growth rate and net assimilation rates are well governed by planting on suitable dates, density, balance use of fertilizer and favorable climatic condition Gull, H. et al. [43].

5.1. Leaf Area Index

The ratio of total leaf area to ground cover is termed as leaf area index (LAI). It is typically increases to maximum after the crop emergence Reddy, S., [44]. According to Azarpour, E., [45], who reported that N supplying during the early season of crop growth, when the availability of soil moisture is adequate, LAI value at lower nitrogen levels is less when compared to the highest rates. The highest LAI achieved at flowering stage (65 days after sowing) and then it was reduced at physiological maturity stage. It is also reported that the percentage of leaf area increment of 30, 60 and 90 kg ha⁻¹ nitrogen treatments compared to the control treatment was 21, 49 and 77%. Arduini, I. et al. [46] observed that nitrogen increased leaf area, which enhances interception photosynthetically active radiation (PAR) and its use efficiency. Rehim, A., [47] showed that application of NPK positively influences LAI and maximum LAI (2.50) obtained at the highest level of 80-60-30 kg NPK ha⁻¹. The minimum LAI (2.19) was reported in the no fertilizer application.

Natajara, T. et al. [17] reported that supplying of 100% P₂O₅ of fertilizer dose accounted significantly increases the leaf area (75.66 dm² m⁻¹ row length), leaf area index (3.36) at 90 DAS, leaf area duration (98.94 days), absolute growth rate (5.116 g m⁻¹ row length day⁻¹) and crop growth rate (0.227 g dm⁻² day⁻¹) during 61 to 90 DAS and grain and straw yield of wheat (35.28, 56.26 q ha⁻¹), respectively at harvest when compared to the other rates. The maximum LAI (3.49) was achieved by the use of B at 2 kg ha⁻¹ which was statistically at par (3.46 and 3.37) with combined application of micronutrient LAI value of 3.21 each after 98 days after sowing. In general, the supply of boron had boosted up the tissue formation with better plant growth and increases its concentration in leaves and results in higher leaf area index.

5.2. Crop Growth Rate

Crop growth (CGR) rate is used extensively in growth analysis of field crop and this physiological parameter is one of the best measures of the total performance of field crops Natajara, T. et al. [17]. Prasad, S., [48] reported that among the nutrient management treatments, application of 144-72-

48 kg NPK ha⁻¹ recorded significantly higher CGR (22.52 and 21.85 gm/m² day) at 30 to 60 days after sowing, respectively, as compared to 96-46-32 kg NPK ha⁻¹ in both the years. At 60 to 90 DAS also it recorded the maximum CGR and found superior over 96-46-32 kg NPK ha⁻¹ (13.21 and 8.68). Lowest CGR was recorded at application of 96-46-32 kg NPK ha⁻¹ on wheat. Hokmalipour, S. et al. [49] also reported that, the highest CGR (52.7 g m⁻² day⁻¹) and Lowest CGR (24.8 g m⁻² day⁻¹) were obtained from 180 kg N ha⁻¹ and control level of nitrogen, respectively. According to Nadim, M. et al. [50] reported that the supplying of boron at a rate of 2 kg ha⁻¹ improved the crop growth rate (33.40 g m⁻² days⁻¹). The author further mentioned that, the application of boron helped for the plants to better utilizing the available nutrients in the soil resulting increased leaf area, high photosynthesis and dry matter accumulation which enhanced crop growth rate of wheat crop.

5.3. Relative Growth Rate

Relative growth rate (RGR) expresses increase of total dry weight per unit time per unit of existing total dry weight. Nitrogen fertilization played a positive role in the growth analysis of wheat cultivars Poma, A. et al. [51]. Hokmalipour et al. [49] conducted an experiment to study the physiological growth indices in corn (*Zea mays* L.) cultivars as affected by different nitrogen fertilizer levels. They reported that RGR was significantly influenced by nitrogen fertilizer levels.

Significantly highest RGR (0.073 gg⁻¹ day⁻¹) was noted from the supplanting of 120 kg N ha⁻¹ in a corn cultivar at 50 days after transplanting. Lowest TDM (0.066 g g⁻¹ day⁻¹) at 50 days after transplanting was observed from control level of nitrogen. Soil application of micronutrients was a significant effect on the RGR of wheat. Significantly highest RGR (0.089 g g⁻¹ day⁻¹) was produced by the application of boron at 3 kg ha⁻¹ Nadim, M. et al. [50]. In general, application of adequate amount micronutrient is a positive response for the crop although the doses of micronutrients still a major concern.

6. Response of Durum Wheat Yield Components and Yield to Macro and Micro-Nutrients

6.1. Yield Components

Cultivation of wheat in monoculture reduces yields and depletes soil nitrogen. However, the supply of macro and micro-nutrients in an adequate may an important tool to improve these production constraints Abera, T. et al. [52]. Several studies showed that nitrogen application increased significantly most wheat yield component Asif, M. et al. [53] Mandic, V. et al. [54]. Previous research finding in Ethiopia application of N fertilizer in the Nitosol zones, a significant and positive response of wheat and it evident in selected yield relative traits such as plant height, number of spikes m⁻² and thousand kernels weight Amsale, T. et al. [55]. Ibrahim,

Y. and Ghfar Mangoub, S., [56] reported that the application of 129 kg N ha⁻¹ increased the number of tillers over the control by 54% of wheat crop.

Results of on-farm experiment conducted near Sinana Research Center on the effects of different N rates on yield and yield related traits of seven durum wheat (*Triticum turgidum* L. var durum) cultivars indicated that compared to control, biomass mean yield was increased by 21.5%, 44.3% and 60.6% by application of 23, 46 and 69 kg N ha⁻¹ treatments, respectively Abdo, W. et al. [57].

Phosphorous play a vital role for enhancing N-fixation through simulating host increase hormone and it is accessible to crop Parnes, R., [58]. According to Kissi, [59], soil utilized P to 30 kg P ha⁻¹ persistently reduced days to heading and physiological maturity. Study by Rehman, S., [60] stated that the use of P the band placement application, resulting improves most yield and yield qualities like tillers number, seed per spike, thousand seeds weight and grain yield, biomass yield and straw yield. Similarly, Alemayehu, B., [61] who reported that total biomass of 586 to 1016 kg ha⁻¹, harvest index 0.14 to 0.22, panicle weight 0.49 to 0.73 g, and seed weight 0.25 to 0.38 mg when P₂O₅ rate was increased from 0 to 9 g P₂O₅ m⁻² of *tef* crop.

Field experiment involved various levels of P fertilizer and application method on wheat crop. The study revealed that the rate of 90 kg P₂O₅ ha⁻¹ resulted the tallest plants height (100 cm), followed by 60 kg P₂O₅ ha⁻¹ (94 cm) and the shortest plant height (91.00 cm) was recorded in the control (0 kg P₂O₅ ha⁻¹). Application of 90 kg P₂O₅ ha⁻¹ to wheat produced significantly increases spike length (12.83 cm), followed by 60 kg P₂O₅ ha⁻¹ (11.33 cm) and shortest spike length (7.33cm) was exhibited in without the application P fertilizer. In general, use of phosphorus at the rate of 90 kg P₂O₅ ha⁻¹ produced highest seed weight (48.16 g), followed by 60 kg P ha⁻¹ (41.00 g) and the smallest seed index (30.83 g) was noted without fertilizer treated plot Noonari, S. et al. [62].

According to Ercoli, L., [63], sulfur nutrient is also very essential for the crop growth cycle and affected the initiation and development phase of plant organs and resulting affected the yield and most yield components. Sulfur fertilizer application entirely before crop planting or in a split application 2/3 of sulfur fertilizer rate at stem elongation gave better yield. This may improve most yield related traits; higher kernel number per spike for the former and higher mean kernel weight for the latter. A high S availability at seeding promoted the development of spike bearing culms and the spike size, while the higher availability at the beginning of stem elongation favored the accumulation of assimilates into grain. Asif, M. et al. [53] suggested that application of boron fertilizer influenced plant height significantly. The highest plant height (90.97 cm) was recorded when the crop was given 2 kg B ha⁻¹, which was statistically identical with 1 and 3 kg B ha⁻¹. The shortest plant height (84.68 cm) was produced by no boron fertilization of the bread wheat. Application of different levels of boron had significantly influenced the number of total tillers plant⁻¹ of wheat. Among the doses, 2 kg B ha⁻¹

produced the highest number of total tillers plant⁻¹ (4.13). The lowest number of total tillers plant⁻¹ (3.61) was recorded when the crop was not fertilized with B Asif, M. et al. [53].

A study made by Muhamed, A. et al. [64] reported that application of micronutrient alone had no any significant effects on the yield and yield components. However, boron application together with macro-nutrients increases the tiller number (307 plant m⁻²) which was statistically at par with 301.25 and 299.92 tillers m⁻² obtained in copper and manganese treatments, respectively. The effects of micro-nutrients are also depending on the type of application. For example, the maximum number of tillers (300.05 plant m⁻²) was recorded in soil application while foliar application showed the minimum tillers (296.15m). Uddi, M. et al. [65] reported that application of Boron significantly increased the number of tillers compared with fertilizer untreated plot.

Muhamed, A. et al. [64] indicated that number of kernel per spike, improved significantly by the application of boron. The highest number of grains per spike (45) was obtained in treatment where boron was applied at 2 kg ha⁻¹ followed by treatment with boron at 1.5 kg ha⁻¹. Control without boron was found to have less number of grains per spike. This author also reported that application of boron increased 1000 grain weight significantly. The maximum 1000 grain weight (46 g) was obtained in highest Boron receiving treatment while minimum was in control. Adera, S., [66] reported that grain yield and yield related traits except grain filling period were significantly affected by blended fertilizer application. In contrast, Esayas, L., [67] reported phenological and growth parameters showed no significant differences due to the blended fertilizer treatments both on days to heading, days to physiological maturity, plant height and number of tillers per plant.

An experiment conducted at Laelay Maychew, Central Tigray, to study the effects of blended fertilizers under planting method on *Vertisols* and *Nitisols* showed that the application of blended fertilizers under the planting method result a significant difference to all yield and yield components. The crop which received blended fertilizers under row planting responded more significantly to plant height, panicle length, seed weight/panicle by 260, 133 and 65%, respectively, than the check on both *Vertisols* and *Nitisols* Berhan, A., [68].

6.2. Grain Yield

A number of previous studies, however, found that wheat is significantly a positive response to nitrogen fertilizer. Interestingly Cossani, C. et al. [69] reported that nitrogen shortages can be crucial in defining grain yield under rain fed conditions. The finding by, Warraichet, E. et al. [70] reported that N suppling up to 120 kg ha⁻¹ in wheat improved grain yield and protein content. Moreover, Dencic, S. et al. [71] and Flores, R. et al. [72] also recorded increased grain yield and its components with adequate application of N nutrient.

A studies made by Amsal, T. and Tanner, D., [73]; Adamu, M., [74] on two soil types in central highlands of Ethiopia, particularly wheat is widely cultivated, the grain yield

increased by about 83, 156, 233, and 288 % on *Vertisol* and by 45, 62, 98, and 150% on *Nitosols* in response to the application of 20.5, 41, 82, and 164 kg N ha⁻¹, respectively. In similar trends, application of 23, 46, and 92 kg P₂O₅ ha⁻¹ resulted in a grain yield increment of 171, 196, and 203% on *Vertisols*, and 71, 90, and 104% on *Nitosols*, respectively. In general, mean value of grain yield in response to nitrogen fertilizer application was 163% on *Vertisols* and 76% on *Nitosols*, compared to without N fertilizer treated one.

Recently, study was made by Mesfin, K. and Tekalign, M., [75], the result showed that the use of 101 and 10 kg N/P ha⁻¹ and 130 and 30 kg N/P ha⁻¹ significantly increases wheat yield on fairly fertile and less fertile Vertisol soils, respectively, at Debre Birhan in central highlands of Ethiopia. Moreover in the finding of Berhan, A., [68], crop response to N a highly decreases when available P in the soil is limited. Both nitrogen and phosphorus were supplied adequately, crop recovery of fertilizer N was approximately 75% compared to about 40% without application of phosphorus fertilizer. The supplying of an adequate amount of nitrogen and phosphorus fertilizer is improving grain yield profitability and increasing nitrogen recovery, whilst reducing the environment impact due to nitrogen fertilizer. In soils, nitrogen fertilizer stimulated uptake of P application Alemayehu, B., [60]. An experiment was carried out on farmers' field, the highest (2.77 t ha⁻¹) and the lowest (2.09 and 2.19 t ha⁻¹) mean grain yield durum wheat were recorded at the application of 11.5, 57.5 and 0 kg P₂O₅, respectively Zhao, F. et al. [34].

There is no a long way use of sulfur (S) fertilizers in Ethiopian agriculture although it is an essential nutrients for plant growth and development. Recent report indicated that the use of sulfur fertilizer is alarming. Sulfur, it required relatively similar amount as that of P Ali, R. et al. [32]. Without adequate application S, crops cannot reach their full potential in terms of grain yield and protein content of the crop Riley, N. et al. [76]. Past research noted that application of right amount Sulphur fertilizers increased by about 36% wheat grain yield Araus, J. et al. [77]. The use of split application of sulfur fertilizer, applying half at planting and a reaming applying at tillering in top application during crop cycle improved wheat crop yield. Recently Ercoli, L. et al. [63] report showed that the highest grain yield was noted with the addition of 60 kg S ha⁻¹ before seeding and 60 kg S ha⁻¹ elongation stage.

Yield is an economical important agricultural output of a particular genotype Habib, M. [78]. According to Muhammad, A. et al. [64] result indicated that micronutrients such as boron had a significant positive effect on wheat yield increment. The author also reported that the application of boron fertilizers was produced the maximum wheat grain yield (5.63 t ha⁻¹). Significant yield advantage of wheat (5.88 t ha⁻¹) was obtained in soil application of boron (1.5 kg ha⁻¹). Similarly [66] obtained 50% more yield with the application of boron (2 kg ha⁻¹). Several other research findings were reports that boron fertilizer application either through soil or foliar had positive correlation with wheat yield Ghatak, R. et

al. [79]. Furtherer more Muhammad, A. et al. [64] reported that the significant highest grain and straw yield (4.42 and 8.52 t ha⁻¹, respectively), was reported when boron was applied at 2 kg ha⁻¹. Lemlem, H. [80], further emphasized that (7.7%) increase in wheat grain yield with adequate application of boron nutrient.

Dagne, C. [81] reported that the companied application of blended, DAP and urea fertilization significantly increased the N, P, K, Zn, Mg and S concentration of *tef* grains in both *Regosols* and *Vertisols* in addition application of blended fertilizer and low seeding rate/banded planting method significantly increased yield, yield components and nutrient uptake by *tef* grain. Compared to the recommended NP fertilizers, mean grain yield of maize was increased by 7.7% with the application of blended fertilizer at Kejo and the same trend was observed at Ongobo CWC, [82]. The increase in grain yield could be attributed to beneficial influence of yield contributing characters and positive interaction of nutrients in the blended fertilizer. On the top of theses, suppling of adequate amount of boron fertilizer can increases wheat yield.

7. The Role of Macro and Micro-Nutrients for Grain Quality Traits of Durum Wheat

7.1. Grain Protein Contents

One of the most important quality traits in cereals, particularly in durum wheat is protein percentage. The protein contents in durum wheat grain ranges from 6% to 20%, depending on variety, environmental conditions, soil type and cultural practices during growth Landi, A. and Guarneri, R. [83]. For the producing of good quality pasta products, the protein contents in the grain should be between 12% and 16% (at 14% mb) is the most optimum. The grain protein content less than 11% will result in poor quality pasta product, on the other hand greater than 16% may be related to lower test weight, which is one of the important quality traits. The past processor industry requires durum semolina to contain over 14% db protein, which corresponds to 15% db grain protein content Boukef, S. et al. [84].

Application of inorganic fertilizers such as nitrogen on wheat crop improves grain protein percentage. The application of adequate amount and right time of nitrogen fertilizers significantly increases grain protein content in durum wheat crop. The maximum protein contents was noted from the suppling of 180 kg N ha⁻¹, while the lowest protein contents was found is the seeds that were obtained from without application of nitrogen fertilizer Abad, A. et al. [85]. Elsewhere research report indicated grain protein content of tested durum wheat cultivars showed 50% increase with N fertilization to reach 15.53% and 15.13%, respectively for ASN and urea Abad, A. et al. [85]. The same results were obtained in durum wheat by Mengistu, B. [86] an average PC of 14.4 and 15.6% under 100 to 150 kg N ha⁻¹, which was

appropriate for semolina production according to industry standards.

According to Panayotova, G. et al. [87] reported a linear increasing in grain protein in response to increase rates of N application. Increasing the supplying of nitrogen fertilizer from nil to 35, 70, 105, 140, and 175 kg N ha⁻¹, protein contents were significantly increased by additional increments of 4.0, 9.0, 16, 20, and 26%, respectively. The concentration of protein in durum wheat grain manifested slight changes after phosphorus fertilization. Average for the period of experiments, the lowest concentration of grain protein was established in check and after fertilization with P160 in 12.37%, and proven the highest was after combined phosphorous rate P 120 with 120 kg N ha⁻¹ Shewry, P. et al. [88].

7.2. Wet Gluten, Dry Gluten Contents and Gluten Index

Gluten proteins functionality is considered the most important components for good quality in durum wheat and hexaploid wheat Efreem, B. et al. [89]. Panayotova, G. et al. [87] reported showed that wet gluten content (WGC) increased significantly in response to increasing the rate of N application. Gerba, L. et al. [90] also reported that wet gluten content of four durum wheat cultivars evaluated ranged from 12.6% to 35.8%. According to Jarvan, M. et al. [91] research report stated that, extremely high gluten content, 54.5% was produced at the application of 240 kg nitrogen fertilizer ha⁻¹. It is significantly higher gluten contents than any of the imported hard/or durum wheat, ever reported in country. Hence, gluten content at all N rates was enormous compared to any of the domestic produce. It increased with increasing N rates. According to Shewry, P. et al. [88] result indicated that the highest proven content of wet and dry gluten was reported after phosphorus rate of 80 kg + N120 kg ha⁻¹ and the lowest after phosphorus fertilization P160 kg ha⁻¹.

The application of Sulfur has also a strong influence on the quality of storage proteins in durum wheat (*Triticum turgidum* L. Var. Durum). Javan, M. et al. [92] reported that in the production trials sulfur increased the protein and wet gluten contents of wheat grain. The wet gluten quality improved considerably, because the content of amino acids increased. Atwell, W. [93] report showed that the baking properties of winter wheat, which had been fertilized with nitrogen but grown under sulfur deficiency, became poor as the stability and quality of dough, the loaf volume and height to diameter ratio decreased. Due to sulfur fertilization all major parameters of winter wheat's baking quality improved: stability and quality number of dough, loaf volume and specific volume and round loaf's height to diameter ratio.

7.3. Hectoliter Weight

Hectoliter weight is a widely recognized primary specification in wheat grading because it is related to the degree of soundness of the wheat. As hectoliter weight drops, the percentage of small, malformed, and broken kernels usually increases. Hence, this test is used in the grading of wheat in many countries Murphy, H. [94]. Hectoliter weight

may range from about 57.9 kg ha⁻¹ for poor quality wheat to about 82.4 kg ha⁻¹ for sound wheat Murphy, H. [94].

8. Conclusion

From this paper, an effort has been made to carefully review past research achievement, limitation, with special emphasis on the aspects of response of durum wheat to macro and micronutrients. Overall, we have identified that fertilizers studies carried out in Ethiopia in the past had serious limitation. Many of which reached on the conclusion that durum wheat is responsive to macro-nutrient but the crop is responsive to micronutrients. Recently, there is an increasing evidence to suggest that the use of micronutrients blended with macronutrients significantly increases plant growth, physiological traits, yield components, yield and most grain quality traits. It is important to underscore these micro-nutrients, however, that any fertilizer recommendation needs to be site and context specific depending on the soil-analysis. Moreover, investment on the inputs (chemical fertilizers) should be also taking in to account to make economic sense for farmers and environment sustainability as a whole.

Therefore, future research should take these limitations into account, and fertilizers management studies should be carried out in a more systematic and coordinated manner covering the wider growing areas.

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