3. Identifying Major Yield- Limiting Nutrients for Bread Wheat (*Triticum aestivum* L.) and Enhancing its Productivity under Irrigation System in Amhara Region

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Abstract

Application of soil nutrients in the form of synthetic fertilizers is the primary option to improve crop productivity and feeding over increased populations. On-farm research was conducted in 2021 under irrigated condition at Mecha and Ayehu Shekudad districts with the objective of identifying the major yield limiting nutrients for bread wheat (Triticum aestivum L.) productivity for western Amhara Region. The experimenthad a total of nine treatments [NPSZnBK, NPSZnK-B, NPSBK-Zn, NPZnBK-S, NPSZnB-K, NSZnBK-P, PSZnBK-N, sole NP, control (no input)] with a randomized complete block design (RCBD) replicated thrice. Improved bread wheat variety (Kekeba) with 150 Kgha^{-1} seed rate was used. Urea, TSP, KCl (muriate of potash), $MgSO_4$, EDTA and Borax was used as a source of N, P, K, S, Zn and B nutrients, respectively. Furrow irrigation method was used using 40cm furrow width. The four rows were irrigated by one furrow every 10-14 days irrigation interval. Except urea, all fertilizer sources were applied at planting using basal application. While, Urea fertilizer was applied in three equal splits at different crop stages. One composite soil sample was taken from each experimental site before plating at 0-20 cm depth and analysed for selected soil physisco-chemical properties. In most of the experimental sites, grain yield, biomass and yield components showed significant responses for Nitrogen followed by Phosphorus. However, either adding or omitting Sulphur, Zinc, Boron and Potassium nutrients Nitrogen is still the primary yield-limiting nutrient followed by Phosphorus under irrigation systems which confirms the rainy season production. Yield without Nitrogen is nearly equal with the yield attended on the control treatment even if all other nutrients existed at optimal levels.

Keywords: Nutrient, bread wheat, Mecha and Ayehu Shekudad

Introduction

Agriculture plays an important role in the Ethiopian economy. It contributes over 35% to the annual GDP, about 80% to the export earnings and it employs over 75% of the population (CSA, 2018). Of the agricultural GDP, the contribution from crop production takes the lion's share which is about 70% or more. Within the crop production system, the share of cereals in area coverage and production potential is about 80% and 85%, respectively (CSA, 2017). The most important three crops (wheat, maize and tef) consume about 60% of the fertilizer inputs, cover 55% of the production area and provide 60% of the annual production potential (CSA, 2017).

Wheat is the most widely cultivated cereal crop in the world, and provides 20% of the protein and calories consumed by the world population (FAOStat, 2013). It is currently the staple food for more than 35% of the global human population (FAOSTAT, 2013). Continues nutrient depletion, newly emerging diseases and pests and unstable weather conditions deriving from climate change are the major threats for declining wheat productivity globally (CIMMYT, 2016). Ethiopia is the second-largest producer of wheat in sub-Saharan Africa, following South Africa (White *et al.,* 2001). The crop covers an area of 1.7 million ha and production of 4.6 million tons (CSA, 2018). From the country, Amhara Region accounts 32.7% of area coverage and 30.3% of volume of production (CSA, 2018). However, average wheat productivity in the Amhara region is about 2.53 tha^{-1} which is below the national average of 2.74 tha^{-1}. Up to 2025, the Ethiopian government plans to save 3 billion USDs of foreign currency that would have been used to import wheat for domestic consumption. To boost wheat productivity and production, Ethiopian governmenthas been striving to produce wheat under irrigation to fulfil national wheat demand through country's production and terminating imported wheat from abroad.

Due to increased use of agricultural inputs (improved seeds, fertilizers and pesticides), agriculture showed a dramatic progress with the annual growth rate of over 8%. Particularly, fertilizer consumption has shown a linear increment from below 37 tons in 1985 jumped to over 134 tons at the end of 1994. Following the RSDEP and PASDEP consecutive five-year plans from 1995 through 2009, fertilizer consumption was increased by 10 tons every year for 16 years. During the subsequent growth and transformation plan of the country (GTP I, 2010 to 2015), the import and consumption rate of fertilizers had grown several folds to 78,000 tons per year. After the introduction of the soil fertility mapping by the Ethiopian Soil Information System (EthioSIS,

2015) and the second growth and transformation plan (GTP II, 2016-2020), the country has increased the fertilizer types from two to over five. For this reason, the annual import and consumption raised to over 100,000 tons per year. Currently, the country imports about 1.4 million tons of multi nutrient fertilizers and projected to use over 2 million tons at the end of 2025 (in GTP III).

In targeting the right fertilizers to the right places, the EthioSIS project team has mapped the soil nutrient status of agricultural lands in Ethiopia and identified that a number of essential nutrients are deficient and critically required for enhancing crop productivity in the country. Based on the map developed by the project team, N, P, K, S, B, Zn, Fe and Cu are the deficient nutrients identified and recommended for enhancing crop production. Even though the newly formulated blended fertilizers needed validation and verification studies, direct demonstration trials were conducted at about 60,000 trial sites by different agricultural scholars and supported EthioSIS project team decision. The country already customized to use multi nutrient fertilizers and made available to farmers through imported market though there is no national or regional conscience on the importance of the fertilizers. Therefore, this activity was designed to validate the EthioSIS based soil nutrient deficiencies and identify the major yield limiting nutrients for bread wheat production under irrigation system in West Amhara Region.

Materials and Methods

Study Area Description: The field experiment was conducted in Mecha and Ayehu Shekudad districts. Both districts are located in North West Ethiopia. Based on Ethiopian traditional agro-ecological classification, Mecha is found under *Weyina dega* (1800 to 2400 m.a.s.l) while, Ayehu Shekudad is found under Dega classification (Mekonen, 2015).

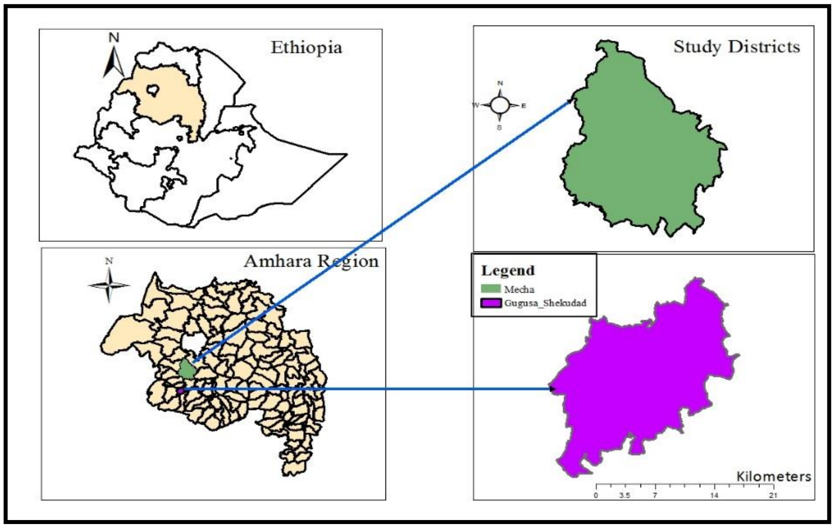

Figure 1. Location of the study districts

Experimental Material: Improved bread wheat variety (Kekeba) with 150 Kgha^{-1} seed rate was used. Urea, TSP, KCl (muriate of potash), MgSO4, EDTA and Borax was used as a source of N, P, K, S, Zn and B nutrients, respectively. Soil auger and core-sampler was used to collect soil samples.

Experimental Methods and Design: The experiment was conducted for one irrigation season in 2021 at a total of four farmers' field. The experiment was conducted using randomized complete block design (RCBD) in three replications. Spacing between rows, plots and blocks were 0.2m, 1m and 1.5m, respectively with a gross plot size of 3.6m x 3m. Furrow irrigation method was used using 40cm furrow width. The four rows were irrigated by one furrow every 10-14 days irrigation interval. Ten centeral rows were harvested as a net plot area in which the data was converted in to a hectare. The experimenthad nine treatments as indicated in Table 1. Except Urea, all fertilizer sources were applied at planting using basal application. While, Urea fertilizer was applied in three equal splits (planting, tilering and butting) stages of the crop. Seed and fertilizer rates were calculated only for net planted plots without considering furrow spaces. However, furrow space was considered as part of netharvestable area.

Table 1. Treatment setup

No	Treatment	Description	Nutrient application rates (Kgha^{-1}) N	P_2O_5	K_2O	S	Zn	B
1	NPSZnBK	All	138	92	30	10	5	2
2	NPSZnK-B	B-omitted	138	92	30	10	5	-
3	NPSBK-Zn	Zn-omitted	138	92	30	10	-	2
4	NPBZnK-S	S-omitted	138	92	30	-	5	2
5	NPSZnB-K	K-omitted	138	92	-	10	5	2
6	NSZnBK-P	P-omitted	138	-	30	10	5	2
7	PSZnBK-N	N-omitted	-	92	30	10	5	2
8	NP	NP alone	138	92	-	10	-	-
9	Control	-	-	-	-	-	-	-

Soil Sampling, Preparation and Analysis: From each experimental site, one composite soil sample before planting was taken from five points following X- pattern sampling technique at the depth of 0-20 cm. The sampled soils were air dried and sieved by (≤2 mm) sieve for analysis. Soil pH, Soil Organic carbon (SOC), Cation Exchange Capacity (CEC), Available Phosphorus (AP), Total Nitrogen (TN) and soil texture were analysed at Adet Agricultural Research Center's Soil Laboratory. Soil pH was determined using 1:2.5 soil-water suspensions ratios according to (Taye *et al.,* 2002). Olsen (1954) was used for AP analysis while Kjeldahl method (Bremner and Mulvaney, 1982) was used for TN analysed. Wet oxidation and ammonium acetate methods were used to determine SOC and CEC respectively.

As indicated in Table 2, Soil pH values of the experimental sites was found from strongly to moderately acidic ranges based on (Tekalign, 1991) which is optimum **(5-6)** for wheat growth and development (Sims, 1996). AP values ranged from low (5-9) to medium (10-18) mgKg^{-1} based on (Cottenie A., 1980) nutrient rating scale. While, based on Tekalign (1991) SOC (1.5-3%) and TN (0.12-0.25%) values found at moderate levels. All CEC readings also found at high rating level (25-40) Cmol$_{(+)}$Kg^{-1} according to Hazelton P. and Murphy (2007). Based on textural triangle, all experimental fields had clay dominated texture.

Table 2.

Parameters	Mecha		Ayehu Shekudad	
	Site 1	Site 2	Site 1	Site 2
pH(H_2O)	5.45	5.24	5.37	5.21
SOC (%)	1.572	1.778	1.856	2.048
CEC	33.24	32.14	33.38	33.20
AP (P-Olsen)	17.11	12.98	17.51	5.27
TN (%)	0.112	0.176	0.196	0.211
Clay (%)	66	66	50	44
Silt (%)	26	26	30	34
Sand (%)	8	8	20	22
Textural class	Clay	Clay	Clay	Clay

Data Collection and Analysis: Agronomic data like plant height, spike length, harvest index (HI) and all biological yields (grain + above ground biomass) were collected. The grain yield was adjusted to 12.5% of moisture content. SAS software version 9.0 was used to analyze all collected agronomic data (SAS Institute, 2002). Least significant difference (LSD) was used for mean separation at 5% probability.

Results and Discussion

Plant Height and Spike Length: Plant height showed significant difference among treatment means except at one experimental site (Table 3). Most of the significant differences generated from N omitted, P omitted and control treatment as compared to the other treatments. Except Nitrogen and Phosphorus, plant height of the testing crop didn’t show clear responses. Addition or omitted of other nutrients other than N and P did not show any difference in plant height. As shown in Table 3 the minimum plant height values recorded in one or all of the three treatments (control, N-omitted or P-omitted). But the maximum values observed in any one of the treatments which received Nitrogen and Phosphorus nutrients together. This showed, the potential of Nitrogen and Phosphorus nutrients to determine yield and yield components of bread wheat. All the trends showed on plant height were reflected on spike length of bread wheat two of the testing sites.

Table3. Plant height and spike length values in the study sites

	Plant height (cm)				Spike length (cm)			
	Mecha		Ayehu Shekudad		Mecha		Ayehu Shekudad	
Treatments	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
NPSZnBK	81.5	79.5	69.6	70.5	8.3	8.3	7.3	7.6
NPSZnK-B	81.9	77.9	66.5	72.5	8.1	7.6	6.8	7.1
NPSBK-Zn	78.6	75.2	72.1	69.0	7.9	8.5	7.4	7.1
NPBZnK-S	81.1	75.4	68.1	68.7	8.2	7.3	7.2	7.3
NPSZnB-K	79.5	77.7	65.7	67.6	8.3	7.5	6.7	7.3
NSZnBK-P	79.9	74.1	68.3	54.5	7.7	7.4	7.3	6.0
PSZnBK-N	69.3	70.1	60.9	66.8	6.9	7.1	6.3	7.1
R-NP	78.7	75.9	68.6	68.7	7.8	7.5	7.3	6.9
Control	68.5	68.6	63.1	57.0	6.8	6.8	6.7	6.0
Pro.Sig	*	NS	*	**	**	NS	NS	*
LSD	8.7	-	6.5	7.8	0.8	-	-	1.0
CV	6.6	9.7	5.7	6.9	5.7	9.1	9.6	8.3

*Note: ** = Highly significant, * = Significant, NS = Non significant*

Grain and Biomass Yields: Except at one site in Mecha district, both grain and biomass yield of bread wheat showed significant difference among treatment means (Table 4). Similar to plant height and spike length, significant difference among treatment means for grain and biomass yields also generated from the N and P omitted as well as control treatments when compared with other treatments. Except at site 2 in Ayehu Shekudad district, the minimum grain yield values recorded were in control treatment followed by Nitrogen omitted treatment. However, the maximum values were observed in any one of the treatments which received Nitrogen and Phosphorus nutrients together.

A clear negative response on both grain and biomass yield of bread wheat was observed when either of the two or both major nutrients (N and P) are omitted. Similar to the rainy season, these two nutrients affected bread wheat productivity and showed their potentials on limiting of biological yields (grain and biomass) under irrigation system in any of the studied west Amhara arable lands which is in line with the finding of (Tadele *et al.*, 2018). Tadele and his colleagues stated that; sulphur, Zinc, Boron and Potassium were not yield-limiting nutrients in Ethiopian soils at this time. Except Nitrogen and Phosphorus nutrients, there was no a significant change on both grain and biomass yields of wheat either due to adding or omitting of Sulphur, Zinc, Boron and Potassium nutrients. Therefore, still it is possible to maximize wheat productivity with feasible economical profits by using optimum rate Nitrogen and Phosphorus source fertilizers. For this evidence, look at how much biological yields of wheat declined at Ayehu Shekudad district in site 2 due to low available Phosphorus reading (Table 2 and Table 4). This might be indicated that it is important to add more Phosphorus amounts on sites having low available Phosphorus values rather than adding Sulphur, Zinc, Boron and Potassium nutrients.

Table 4. Grain and biomass yield of bread wheat values in the study districts

	Grain yield ($Kgha^{-1}$)				Biomass yield ($Kgha^{-1}$)			
	Mecha		Ayehu Shekudad		Mecha		Ayehu Shekudad	
Treatments	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
NPSZnBK	3416.7	2324.8	2635.7	2932.8	7500.0	5208.3	5255.2	5863.9
NPSZnK-B	3529.4	1895.7	2610.3	2669.7	7638.9	4166.7	5345.5	5675.0
NPSBK-Zn	3714.7	2338.9	2501.2	2919.3	7916.7	5208.3	5284.7	5744.4
NPBZnK-S	3533.6	1869.5	2634.4	2656.5	8194.4	4375.0	5487.8	5325.0
NPSZnB-K	3524.9	1922.1	2644.4	2817.7	6597.2	4652.8	5467.0	5641.7
NSZnBK-P	3431.8	1945.8	2486.8	1540.1	8333.3	4236.1	5024.3	3191.7
PSZnBK-N	2170.8	1458.8	1635.2	2423.3	4583.3	3229.2	3368.1	4897.2
R-NP	3381.8	1995.4	2437.6	2911.2	7187.5	4375.0	5269.1	6055.6
Control	1883.9	1107.5	1546.6	1572.6	3958.3	2430.6	3175.3	3236.1
Pro.Sig	*	NS	**	**	*	NS	**	**
LSD	1086.3	-	550.8	577.8	2945.2	-	1140.9	1051.4
CV	19.9	32.5	13.7	13.5	25.0	28.3	13.7	12.1

*Note: ** = Highly significant, * = Significant, NS = Non significant*

Similar to the individual experimental sites, all the biological yields and yield components showed significant difference among treatment means (Table 5). As discussed for the individual parameters, in the combined analysis, the significant differences were observed in control and N omitted treatments as compared with other treatments. Except the control and N omitted treatments other treatments didn't show any significant difference with each other in yields and yield components. In other words, yield without Nitrogen is nearly equal sometimes below the yield attends on the control treatment even if all other nutrients existed in optimal levels. As shown from individual and combined analysis results, Nitrogen is still the leading yield limiting nutrients in Ethiopian soils followed by Phosphorus which is line with (Tadele *et al.,* 2022). He and his colleagues explained that the yield-limiting nutrients to produce maize in major maize-growing areas in Amhara region were Nitrogen and Phosphorus in the respective order.

Table 5. Combined analysis data of biological yields and yield components of the study sites

Treatments	Plant height (cm)	Spike length (cm)	Grain yield (Kgha^{-1})	Biomass yield (Kgha^{-1})
NPSZnBK	76.9	8.0	2792.4	5987.8
NPSZnK-B	75.4	7.5	2678.5	5717.0
NPSBK-Zn	75.3	7.9	2851.6	6136.6
NPBZnK-S	74.9	7.6	2679.1	6019.1
NPSZnB-K	74.3	7.5	2697.2	5572.3
NSZnBK-P	74.1	7.5	2621.4	5864.6
PSZnBK-N	66.8	6.8	1754.9	3726.9
R-NP	74.4	7.5	2604.9	5610.5
Control	66.7	6.8	1512.6	3188.1
Pro.Sig	*	**	**	**
LSD	6.6	0.6	710.9	1590.3
CV	9.6	9.2	30.7	31.8

*Note: ** = Highly significant, * = Significant*

Conclusion

In most of the experimental sites, both biological yields and yield component did show significant and negative responses for Nitrogen followed by Phosphorus. Either adding or omitting of sulphur, Zinc, Boron and Potassium nutrients didn't show any significant changes on all biological yields. In our study, Nitrogen is the leading yield limiting nutrient followed by Phosphorus nutrient which is similar to with the rainy season production. Yield without Nitrogen is nearly equal sometimes below the yield attends on the control treatment even if all other nutrients existed in optimal levels. Therefore, it is still possible to enhance wheat productivity under irrigation using sole Nitrogen and Phosphorus fertilizers sources with integrating other improved wheat production technologies. However, frequent revision of soil fertility status is too important for updating nutrient type requirements for enhancing wheat productivity and production in Amhara region.

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