



Wheat Response to N-P-S-Zn-B and Urea Fertilizers Across Soil Types and Agro-Ecologies, Arsi Zone of Oromia

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To cite this article:

Mengistu Chemed, Anbessie Debebe, Gobana Negasa, Dugasa Gerenfes, Kasu Tadesse, Asrat Mekonnen. Wheat Response to N-P-S-Zn-B and Urea Fertilizers Across Soil Types and Agro-Ecologies, Arsi Zone of Oromia. *American Journal of BioScience*.

Vol. 10, No. 4, 2022, pp. 143-148. doi: 10.11648/j.ajbio.20221004.13

Received: July 5, 2022; **Accepted:** August 9, 2022; **Published:** August 29, 2022

Abstract: Experiments were conducted in three consecutive cropping years (2017, 2018 and 2019) at two districts (Gedeb-Hasasa and Lemu-Bilbilo) on different farmers fields, to determine optimum rates of N-P-S-Zn-B and urea fertilizers for wheat crop by varying levels of N-P-S-Zn-B (0, 100, 150, 200, 250 kg ha⁻¹), urea (0, 150, 250, 350 kg ha⁻¹) and blank recommended NP. The soil result of the sites crop after harvest revealed that, treatments were significantly ($p < 0.05$ and $p < 0.01$) affected pH, total N organic matter and available P for samples collected from experimental sites of wheat crop, and different fertilizer level had significant ($p < 0.05$) effect on crop after harvest pH contents of soil at Gedeb-Hasasa. The applied treatments also significantly ($p < 0.05$ and $p < 0.01$) affected pH, total N, organic carbon and available P for samples collected from trial sites on both farmer field and sub-station of the crop at Lemu-Bilbilo. Combined levels of the two fertilizers were significantly ($p < 0.05$) affected grain and biomass yields at both districts. The maximum grain and biomass yield (6137 and 13192 kg ha⁻¹) in the first year and minimum (3786 and 7651 kg ha⁻¹) in the second year of cropping season. Significant grain and biomass yield (6234 and 13518 kg ha⁻¹) were also received from the application of 250 and 350 kg ha⁻¹ N-P-S-Zn-B and urea, respectively at Gedeb-Hasasa. Maximum grain and biomass yield (7043 and 13516 kg ha⁻¹) in the third year and minimum (4265 and 9343 kg ha⁻¹) in the first year of cropping season were recorded, and significant grain and biomass yield (6235 and 12865 kg ha⁻¹) were also obtained from the application of 250 and 350 kg ha⁻¹ N-P-S-Zn-B and urea, respectively, at Lemu-Bilbilo.

Keywords: Experiment, N-P-S-Zn-B, Urea, Fertilizers, Wheat, Arsi, Oromia

1. Introduction

Wheat is among the top cereal crops grown in the Ethiopian highlands dominated by two wheat species. About 80 percent of wheat produced in Ethiopia is bread wheat (*Triticum aestivum*) of which 60 percent is grown in spring seasons [1]. Ethiopia is also considered to be the center of genetic diversity of durum wheat (*Triticum turgidum* L var durum), which is grown on Vertisols of the central and northern highlands of Ethiopia between 1800-2800 m [2]. In Arsi, Bale, and Shewa regions, the soil, moisture and disease conditions in the 1900-2300 m altitude zone are conducive environment for the production of early- and intermediate-

maturing varieties of bread wheat. This is estimated to comprise 25 percent of the total wheat area, while the remaining 75 percent falls in the 2300-2700 m zone. Soil types used for wheat production vary from well-drained fertile soils to water logged heavy vertisols [3].

China, India and Russia are among the world's top three wheat producers and Ethiopia is the largest wheat producer in Sub-Saharan Africa. Though Ethiopia ranks 31st in the world with 4.2 million quintals produced on 1.7 million hectares of land, it is the 67th country in wheat yield, even far below many SSA countries. This production volume covers 5.8

percent and 16.2 percent of the total wheat production in the world and in Africa [4].

Agricultural production has been highly dependent on natural resources for many years [5]. However, increased human population and other factors have degraded the natural resources in Ethiopia [6, 7]. Continuous cropping and inadequate replacement of nutrients removed in harvested materials or lose through leaching has been the major causes of soil fertility decline [8]. The removal of soil nutrients in Ethiopia is linked to cultural practices such as low fertilizer use, removal of vegetative cover and burning plant residues [9].

In the past, only nitrogen and phosphorus were considered to be the limiting nutrients in Ethiopia [10]. However, most of soils in Ethiopian highlands are poor in available plant nutrients and organic matter content [11]. Recently, the results of national soil fertility mapping initiative has also indicated that other nutrients including K, S, Fe, B and Zn are also found to be deficient in these soils. Different combinations of fertilizers containing elements such as N, P, K, S, B, Zn, Cu, Fe, etc. are formulated for different agro-ecologies [12]. Thus, there is very important to develop location and agro-ecology based fertilizer recommendation to increase the productivity of crops.

This experiment was designed to examine the response of bread wheat to N-P-S-Zn-B and urea fertilizers, specifically, to determine optimum N-P-S-Zn-B and urea fertilizer rates for wheat crop; and to quantify their comparative advantage over the traditional fertilizer recommendation.

2. Materials and Methods

2.1. Area Descriptions

The experiment was carried out on farmers' fields and research stations for three cropping seasons during 2017-2019 at Gedeb-Hasasa and Lemu-Bilbilo districts in Arsi zone of Oromia, South-eastern Ethiopia. The average weather data recorded on the weather station located near the study areas from the years 2017 - 2019 indicate that the total annual rainfall for Gedeb-Hasasa district were 496.1, 571.5 and 640.0 mm respectively, and the annual mean minimum

and maximum daily air temperature for the consecutive years were (7.3, 6.9, 7.0°C) and (17.9, 18.1, 21.0°C) respectively. Similarly, the total annual rainfall for Lemu-Bilbilo district were 956.6, 803.5 and 990.6 mm respectively, and the annual mean minimum and maximum daily air temperature for the consecutive years were (4.7, 2.9, 3.3°C) and (18.5, 20.3, 20.5°C) respectively.

2.2. Design and Treatments

The experiment was set in combined RCBD by varying levels of N-P-S-Zn-B fertilizer (0, 100, 150, 200, 250 kg ha⁻¹), urea (0, 150, 250, 350 kg ha⁻¹) and recommended NP with three replications. The size of each experimental gross plot was 2.6 m * 4 m (10.4 m²). The bread wheat variety used for the experiment at Gedeb-Hasasa and Lemu-Bilbilo were Wane and Lemu, respectively. Both fertilizers which varied depending on treatments were applied as side banding at sowing time, urea was applied two times in split half at planting and the remaining at 35 days after planting, the other agronomic practices were kept uniform for all treatments.

2.3. Soil Sampling and Analysis

Surface soil, 0 - 20 cm depth, were collected from the entire experimental field before planting and after harvesting. The soil was daily air dried and made fine by using mortar and pestle. The fined soil was passed through 2mm sieve and the soil pH, Available P, Total N and Organic matter were determined at Kulumsa Agricultural Soil Laboratory. Soil pH (H₂O) was measured by using a pH meter in a 1:2.5 soil: water ratio. Soil organic carbon was estimated by the Walkley-Black wet oxidation method. Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method, and available P was determined using the standard Olsen extraction method. Accordingly, The soil analysis result before planting at Gedeb-Hasasa and Lemu-Bilbilo districts indicated that the pH value were 5.78 and 5.64 (moderate) [13], available phosphorus 15.72 and 11.35 ppm, high [14], total N were 0.14% (medium) and 0.26% (high) and Organic matter were 3.96 and 5.55%, medium and high, respectively [15] (Table 1).

Table 1. Soil analysis results (0-20 cm) pre-planting of wheat from the trial sites in Gedeb-Hasasa and Lemu-Bilbilo districts.

Location	pH (1:2.5)	Av. P (ppm)	Total N (%)	OC (%)	OM (%)
Gedeb-Hasasa	5.78	15.72	0.14	2.29	3.96
Lemu-Bilbilo	5.64	11.35	0.26	3.22	5.55

2.4. Yield Data Collection

Data of seedling density, tiller per plant, plant length, number of spike, spike length, seed per spike, grain yield, biomass yield, thousand seed grain weight and hecto-liter weight were recorded from each plot. Grain and biomass yields were analyzed gravimetrically by using sensitive balance and recorded in units of gram.

2.5. Statistical Analysis

The ANOVA procedure of statistical analysis system [16] was used for performing the significance of differences in grain and biomass yields. A separation of means was done by least significant difference (LSD) test was found significant at $P \leq 0.05$.

3. Results and Discussions

3.1. Effect of Fertilizer Application on Soil Chemical Properties

The soil result after crop harvest at Gedeb-Hasasa showed that the application of treatments significantly ($p < 0.05$ and

$p < 0.01$) affected pH, total N organic matter and available P for samples collected from trial sites of wheat crop. Fertilizer levels had significant ($p < 0.05$) effect on post-harvest pH contents of soil. A significant improvement was not observed in chemical contents of soil compared to the contents of the soil result before treatment application (Table 2).

Table 2. Effect of fertilizer levels on soil chemical properties after wheat harvest in Gedeb-Hasasa district.

N-P-S-Zn-B + Urea (kg ha ⁻¹)	pH (1:2.5)	AvP (ppm)	Total N (%)	OC (%)	OM (%)
0 + 0	5.80	14.37	0.16	2.36	4.07
100 + 150	5.73	15.25	0.15	2.31	3.98
100 + 250	5.71	11.83	0.16	1.98	3.41
100 + 350	5.90	15.25	0.14	1.80	3.24
150 + 150	5.78	13.93	0.13	1.46	2.52
150 + 250	5.75	12.81	0.16	2.28	3.93
150 + 350	5.89	12.22	0.15	1.74	3.00
200 + 150	5.89	17.30	0.13	1.33	2.29
200 + 250	5.75	15.98	0.16	2.33	4.02
200 + 350	5.71	18.71	0.15	1.54	2.66
250 + 150	5.71	12.22	0.17	2.19	3.78
250 + 250	5.86	21.04	0.14	1.58	2.73
250 + 350	5.76	13.75	0.16	2.27	3.92
RNP	5.87	21.11	0.18	2.36	4.06
Mean	5.79	5.79	5.79	5.79	5.79
F-probability	***	***	*	***	***
LSD _{0.05}	0.08	1.05	0.02	0.23	0.41
CV (%)	0.78	4.12	9.04	7.34	7.38

, * = significant at $p < 0.05$ and $p < 0.001$; RNP = Recommended Nitrogen and Phosphorus.

The soil result after crop harvest in Lemu-Bilbilo, indicated that treatments were significantly ($p < 0.05$ and $p < 0.01$) affected pH, total N, organic carbon and available P for samples collected from trial sites on both farmer field and sub-station of

wheat crop. A significant increase was indicated in soil available P and organic carbon contents at post-harvest of the experimental farmers' fields in contrast to the contents of the soil result before treatment application (Table 3).

Table 3. Effect of fertilizer levels on soil chemical properties after wheat harvest in Lemu-Bilbilo district.

N-P-S-Zn-B + Urea (kg ha ⁻¹)	Farmers field					Sub-station				
	pH (1:25)	AvP (ppm)	TN (%)	OC (%)	% OM	pH (1:25)	AvP (ppm)	Total N (%)	OC (%)	OM (%)
0 + 0	4.84	12.03	0.27	4.07	7.01	5.56	18.92	0.20	1.81	3.12
100 + 150	4.81	12.95	0.29	4.28	7.38	5.63	16.62	0.24	1.48	2.54
100 + 250	4.77	13.43	0.29	4.23	7.29	5.61	19.50	0.19	2.20	3.79
100 + 350	4.58	13.72	0.29	4.24	7.31	5.71	15.80	0.22	2.60	4.48
150 + 150	4.78	13.02	0.29	4.56	7.86	5.54	16.13	0.19	1.38	2.38
150 + 250	4.81	14.05	0.24	3.91	6.74	5.72	17.27	0.20	2.14	3.69
150 + 350	4.77	13.74	0.29	4.22	7.27	5.69	15.58	0.19	1.65	2.84
200 + 150	4.77	16.47	0.30	4.19	7.22	5.64	18.91	0.20	2.14	3.69
200 + 250	4.73	14.95	0.30	3.99	6.88	5.57	16.84	0.22	2.08	3.59
200 + 350	4.65	14.38	0.30	4.17	7.19	5.54	17.48	0.19	2.34	4.03
250 + 150	4.76	14.17	0.24	4.33	7.46	5.64	16.93	0.19	1.69	2.92
250 + 250	4.66	14.76	0.30	4.08	7.02	5.58	16.59	0.20	2.39	4.12
250 + 350	4.67	16.45	0.29	4.32	7.44	5.35	15.95	0.23	2.22	3.82
RNP						5.48	16.99	0.23	2.46	4.24
Mean	4.74	14.16	0.28	4.20	7.24	5.59	17.11	0.21	2.04	3.52
F-probability	**	***	***	***	***	***	***	***	***	***
LSD _{0.05}	0.11	1.44	0.03	0.14	0.24	0.13	1.38	0.02	0.27	0.46
CV (%)	1.38	6.05	5.37	1.96	1.97	1.39	4.88	6.95	7.91	7.91

, * = significant at $p < 0.05$ and $p < 0.001$; RNP = Recommended Nitrogen and Phosphorus.

3.2. N-P-S-Zn-B and Urea Fertilizers Effect on Yields of Wheat

Greater grain and biomass yield (6137 and 13192 kg ha⁻¹) in year-1 and lower (3786 and 7651 kg ha⁻¹) in year-2 cropping

season, and significant grain and biomass yield (6234 and 13518 kg ha⁻¹) were obtained from the treatment of 250 and 350 kg ha⁻¹ N-P-S-Zn-B and urea, respectively at Gedeb-Hasasa district (Table 4).

Table 4. Grain (GY) and biomass (BY) yield analysis results on effect of N-P-S-Zn-B and urea fertilizers for wheat crop at Gedeb-Hasasa and Lemu-Bilbilo districts.

Factors	Gedeb-Hasasa		Lemu-Bilbilo	
	GY (kg ha ⁻¹)	BY (kg ha ⁻¹)	GY (kg ha ⁻¹)	BY (kg ha ⁻¹)
Year				
2017	6137a	13192a	4265c	9343c
2018	3786c	7651c	4836b	10230b
2019	5947b	12736b	7043a	13516a
LSD _{0.05}	158.1	433.7	210.4	543.3
Fertilizers rate (N-P-S-Zn-B + Urea), kg ha ⁻¹				
0 + 0	3067f	6948d	3166g	6105f
100 + 150	4955e	10562c	4611f	9502e
100 + 250	5608cd	12104b	5000ef	10088e
100 + 350	5895abc	12298b	5081de	10372de
150 + 150	5292de	10651c	4882ef	10129e
150 + 250	5979abc	12758ab	5709bc	11545bc
150 + 350	5772bc	12754ab	6262a	12579ab
200 + 150	5766bc	12307b	5472cd	11590bc
200 + 250	6088ab	12803ab	5886abc	11837abc
200 + 350	6171a	12885ab	6115ab	12645ab
250 + 150	5699c	12085b	5527c	11298cd
250 + 250	6159a	13046ab	6006ab	12834a
250 + 350	6234a	13518a	6235a	12865a
CV (%)	9.5	12.3	12.4	15.6
LSD _{0.05}	383.7	1057.3	438.0	1131.0

The higher grain and biomass yield (7043 and 13516 kg ha⁻¹) in 2019 and minimum (4265 and 9343 kg ha⁻¹) in year-1 cropping season, and significant grain and biomass yield (6235 and 12865 kg ha⁻¹) were recorded from the treatment received 250 and 350 kg ha⁻¹ N-P-S-Zn-B and urea, respectively at Lemu-Bilbilo district (Table 4).

The highest result of yield harvest index, HLW and TKW (45.5% and (78.4 gL⁻¹) in year-1, (43.8 g

and lowest (40.0% and 75.9 gL⁻¹) in year-3; and (41.7 g) in year-1 and 2 cropping season were obtained, respectively at Gedeb-Hasasa. Significant value of yield harvest index (44.6%) from the application of 100 and 350 kg ha⁻¹, HLW (78.5 gL⁻¹) from the application of 100 and 250 kg ha⁻¹ and thousand seed weight (43.2 g) from the application of 250 and 250 kg ha⁻¹ N-P-S-Zn-B and urea, respectively (Table 5).

Table 5. Yield harvest index (HI), hectoliter weight (HLW) and thousand seed weight (TKW) result on effect of N-P-S-Zn-B and urea for wheat crop at Gedeb-Hasasa and Lemu-Bilbilo districts.

Factors	Gedeb-Hasasa			Lemu-Bilbilo		
	HI (%)	HLW (gm hL ⁻¹)	TKW (gm)	HI (%)	HLW (gm hL ⁻¹)	TKW (gm)
Year						
2017	45.5a	78.4a	41.7b	40.6b	82.7a	44.9b
2018	44.4b	78.2a	41.7b	44.3a	82.7a	45.3b
2019	40c	75.9b	43.8a	45.1a	79.5b	46.7a
LSD _{0.05}	0.9	0.4	0.7	1.0	0.3	0.5
Fertilizer rate (N-P-S-Zn-B + Urea), kg ha ⁻¹						
0 + 0	40.3d	76.8c	42.3ab	45.1a	82a	45.8abc
100 + 150	42.1cd	77.0bc	41.5b	42.6bc	81.7ab	45.9ab
100 + 250	43.3abc	78.5a	42.1ab	43.9abc	81.8ab	45.7abc
100 + 350	44.6a	77.3bc	42.4ab	43.8abc	81.8ab	45.7abc
150 + 150	44.3ab	77.2bc	42.7ab	42.6bc	81.5ab	45.7abc
150 + 250	43.2abc	77.1bc	42.7ab	43.7abc	81.7ab	46.1a
150 + 350	42.2bcd	77.2bc	42.2ab	43.9abc	81.2b	45.7abc
200 + 150	42.4bcd	77.3bc	43.0ab	42c	81.6ab	45.8abc
200 + 250	44.2abc	77.8ab	43.0ab	44.3ab	81.6ab	45.9ab
200 + 350	43.9abc	77.4bc	42.6ab	43.1abc	81.6ab	45.5abc
250 + 150	43.0abc	77.3bc	42.8ab	42.8bc	81.6ab	45.4abc
250 + 250	44.1abc	77.6bc	43.2ab	42.3bc	81.6ab	45bc
250 + 350	42.6abc	77.4bc	42.8a	43.1abc	81.5ab	44.9c
CV (%)	6.8	1.6	5.4	7.3	1.1	3.4
LSD _{0.05}	2.1	0.9	1.7	2.1	0.6	1.0

The highest record of harvest index (44.3%) in the second year, HLW (82.7 gL⁻¹) in year-1 and 2, thousand

seed weight (46.7 g) in year-3, and the lowest (40.6%) in year-1, and (79.5 gL⁻¹) in year-3 and (45.3 g) in year-2

cropping season were obtained, respectively at Lemu-Bilbilo district. The value difference of harvest index and HLW (45.1% and 82.0 gL⁻¹) from the control, and

thousand seed weight (46.1 g) from the application of 150 and 250 kg ha⁻¹ N-P-S-Zn-B and urea were recorded, respectively (Table 5).

Table 6. Effect of N-P-S-Zn-B and urea fertilizers for bread wheat on grain yield (GY), biomass (BY) and harvest index (HI) analysis result at Gedeb-Hasasa and lemu-Bilbilo districts (2019 cropping season).

N-P-S-Zn-B + Urea, kg ha ⁻¹	Gedeb -Hasasa			Lemu-Bilbilo		
	GY (kg ha ⁻¹)	BY (kg ha ⁻¹)	HI (%)	GY (kg ha ⁻¹)	BY (kg ha ⁻¹)	HI (%)
control	2926f	6516e	38.6bcd	4825d	8792f	45.8ab
100 + 150	4903e	10064d	41.2ab	6550bc	12687de	41.5c
100 + 250	5856cd	13591ab	39.9abcd	7008ab	13557bcd	41.7c
100 + 350	6450abc	13295ab	41.4ab	5757cd	11006e	43.9abc
150 + 150	5786d	11262cd	42.2a	6581bc	12799cde	42.2bc
150 + 250	6490ab	13955ab	39.1bcd	7445ab	13882bcd	44.9abc
150 + 350	6561ab	14092ab	40.1abcd	7837a	14720abc	43.9abc
200 + 150	6056abcd	12672bc	41ab	7047ab	13684bcd	42.1bc
200 + 250	6615ab	13736ab	41.5a	7847a	14441abcd	44abc
200 + 350	6440abc	13849ab	39.4abcd	7688a	14706abc	42.8abc
250 + 150	6000bcd	13436ab	37.5d	7332ab	13698bcd	42.8abc
250 + 250	6473abc	14064ab	40.8abc	7770a	16394a	35.9d
250 + 350	6637a	15005a	38cd	7866a	15339ab	41.8c
RNP	4705e	10264d	38.5bcd	5892c	11182e	46a
Mean	5850	12557	39.9	6960	13349	42.8
CV (%)	9.4	12.8	6.5	12.4	12.8	5.1
LSD _{0.05}	6633.7	1846.7	3.0	996.0	1964.2	3.7

RNP = Recommended Nitrogen and Phosphorus.

A year-3 (2019) result revealed that, the maximum grain biomass yield (6637 and 15005 kg ha⁻¹) were recorded from the application of 250 and 350 kg ha⁻¹ N-P-S-Zn-B and urea fertilizers rate; and minimum at the control (2926 and 6516 kg ha⁻¹) and pervious (blanket) recommendation (4705 and 10264 kg ha⁻¹), respectively. Thus, the blanket recommendation has got grain (37.8%) yield advantage over the control; and 4.0 to 29.1% yield lose over the other remaining treatments at Gedeb-Hasasa district. Similarly, the highest grain and biomass yields (7902 and 17467 kg ha⁻¹) were received from the application of (150, 250) and (250, 250) kg ha⁻¹ N-P-S-Zn-B and urea fertilizers rate; and lowest at pervious (blanket) recommendation (4438 and 8694) kg ha⁻¹) and the control (4818 and 9268 kg ha⁻¹), respectively. Thus, the control has got grain (7.9%) yield advantage over the blanket recommendation at Lemu-Bilbilo district (Table 6).

4. Conclusions

The results of trial sites' soil after crop harvest showed that, treatments were significantly ($p < 0.05$ and $p < 0.01$) affected pH, total N organic matter and available P for samples collected from trial sites of wheat crop. Fertilizer levels had significant ($p < 0.05$) effect on crop after harvest pH contents of soil at Gedeb-Hasasa. Similarly, treatments were significantly ($p < 0.05$ and $p < 0.01$) affected pH, total N, organic carbon and available P for samples collected from trial sites on both farmer field and sub-station of wheat crop at Lemu-Bilbilo.

The highest grain and biomass yield (6137 and 13192 kg ha⁻¹) in year-1 and minimum (3786 and 7651 kg ha⁻¹) in year-2 cropping season, and significant grain and biomass yield

(6234 and 13518 kg ha⁻¹) were obtained from treatment received 250 and 350 kg ha⁻¹ N-P-S-Zn-B and urea, respectively.

The maximum grain and biomass yield (7043 and 13516 kg ha⁻¹) in year-3 and minimum (4265 and 9343 kg ha⁻¹) in year-1 cropping season, and significant grain and biomass yield (6235 and 12865 kg ha⁻¹) were recorded from the treatment received 250 and 350 kg ha⁻¹ N-P-S-Zn-B and urea, respectively.

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